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FLOWERS

THEIR ORIGIN SHAPES
PERFUMES & COLOURS

J·E·TAYLOR·F·G·S F·L·S.

FLOWERS;

THEIR ORIGIN, SHAPES, PERFUMES, AND COLOURS.

PERIANTHED PLANTS.

PLATE I.

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FLOWERS:

THEIR ORIGIN, SHAPES, [illegible]

AND COLOURS.

By

JOHN TAYLOR, Ph. D., F.L.S., [illegible]

LONDON:
CHEF & BOGUE, 192, PICCADILLY, W.
1876.

191. j

FLOWERS;

THEIR ORIGIN, SHAPES, PERFUMES, AND COLOURS.

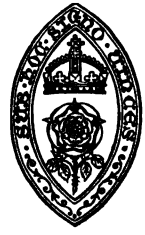
BY

J. E. TAYLOR, PH.D., F.L.S., F.G.S., ETC.

AUTHOR OF 'GEOLOGICAL STORIES,' 'HALF-HOURS AT THE SEA-SIDE,' 'HALF-HOURS IN THE GREEN LANES,' 'THE AQUARIUM,' ETC.

Illustrated with 32 *Coloured Figures by Sowerby, and* 161 *Woodcuts.*

"And 'tis my faith that every flower
Enjoys the air it breathes."—WORDSWORTH.



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1878.

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PREFACE.

WE have endeavoured in the following chapters to place before that portion of the intelligent public who have the desire, but neither the time nor opportunity to make themselves acquainted with natural science, the charming and suggestive results of modern botanical investigation. Flowers have always had an attraction superior to any other group of organic objects, although many people have associated their scientific study with categories of dry names and terms. The objection to botany on this score is fast dying out; its students are everywhere increasing; and the organization of Metropolitan and Provincial Field-Clubs and Natural History Societies is giving an impetus to science such as it never enjoyed before. Numbers of hard-worked men and women, wearied with brain as well as manual labour, are learning to restore their lowered energies by such country outings as the pursuit of natural science involves.

Every day we are proving that "man liveth not by bread alone;" and that sunny blue skies, laughing

streams, and flower-bedecked fields are full of lofty and even spiritual teachings. The Organic Unity of Creation, for which thinkers have long sighed and laboured and suffered, has appeared above the horizon, and is each day becoming more manifest to us. A clearer conception of Creational Power and Wisdom must naturally spring from more correct ideas of the laws by which the Life of our planet originated, and which still continue to govern it.

In conclusion, we have to express our sincere thanks to various kind friends for hints and suggestions, but particularly to Thomas Birch Wolfe, Esq., of Brighton, a well-known botanist, who kindly revised the proofs of the following pages.

IPSWICH, *April*, 1878.

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FLOWERS.

CHAPTER I.

THE OLD AND THE NEW PHILOSOPHY OF FLOWERS.

NO conclusion drawn from natural history has been regarded as more definitely settled than that flowers, and, indeed, plants in general, were created solely for the delight or use of man. Not many years ago it would have been deemed heretical to deny this dogmatical conclusion. But natural science has lately undergone a revolution very similar to that which took place in astronomy three centuries ago. The Copernical theory of the universe was at first regarded as contrary to the teachings of the Bible. The Romish Church authoritatively denounced it, just as she has recently denounced Darwinism. She has since conceded to the new philosophy of astronomy, and now has Professors at her own universities teaching those very scientific doctrines which the Church herself originally persecuted! May it not be so with the modern doctrine of evolution? Already there are

signs and tokens of such an event, for more than one Professor in even Catholic Colleges holds views bordering on evolution, if they are not an integral part of that comprehensive philosophy.

It is but a short period since the nebular hypothesis was most vigorously attacked for its supposed materialistic tendencies. But discovery after discovery in astronomy has rendered it so probable that it has now become a "working theory," that is, one by which practical astronomers find it easiest to test some parts of their work. Spectroscopic analysis has made it more probably truthful than ever; and thus the mind is presented with the almost certain fact that all the matter in the universe, dispersed as nebulæ, broken up into stars, revolving as planets, or wandering as comets, is bound together in one physical and chemical brotherhood.

None will deny that we are able to extend our vision into the unknown all the farther, from the extended base which science has thus laid down. And, although by searching we cannot find out God, we may certainly form a grander and worthier idea of Him, from a better and wider acquaintance with His works. Who will now deny that the magnificent discoveries in astronomy, due first to the Copernican and Newtonian theories, and then to the perfected instruments which so widely extended man's capability of investigating the starry heavens, have not handed over to theology a worthier estimate of Deity than the

olden notions which mediæval theology protected? Religion must be a gainer, not a loser, not only by the truth, but, in proportion to the amount and degree of the truth which she may hold.

One of the most significant of the results of modern scientific discovery is that it tends to draw things which have been deemed remote more nearly together, and even to establish actual relationships which are almost startling by their novelty. Philosophy has always had for its aim the comprehension of the entire universe—physical, organic, and *moral*,—in its unity. When the friends of religion have lost the terror which has deprived some of them of their heads, they will acknowledge they had everything to gain, and nothing to lose, by the novel doctrines regarding flowers now taught by our leading naturalists, and which it will be our purpose to set forth in the following pages. We hold that, even now, in the minds of the most intelligent and thoughtful, and before long in those of the average educated, the new philosophy of flowers will excite more reverence and admiration of Creatorial wisdom than the older teachings could educe, and that also in directions which the old views could not possibly indicate. The teachings of modern botanists and naturalists concerning flowers and insects are of a higher and more spiritual kind than those they have replaced; and the whole subject has been lifted to a higher and broader platform, whence a better and clearer view can be obtained of

the subjects discussed, and their general and special meanings.

It is hardly necessary to do more than hint that, even in the minds of the educated (and more distinctly so in those of the uneducated who think at all), the idea which has prevailed so long that it may be said to have rooted itself in the convictions, is that vegetation of all kinds was created *purposely* to suit human needs. A century ago none would have doubted it. Some of the so-called "evidences of Christianity" hastily pointed out its existence in favour of the "design" argument. When geology arose to be a science, and its teachings were listened to, the stories it had to tell of ancient extinct types of vegetation considerably weakened the effect of this argument. Here were certain kinds of plants which lived and died before man was created! With the elasticity which seems fortunately characteristic of theology, the latter overcame this difficulty, and now conveniently settled itself down on the broader conclusion that there was a planned relationship between the existing vegetable world and mankind.

A skilful casuist could still make out a "case." But what we are concerned with is to indicate the scientific inadequacy of such arguments. The new philosophy of flowers would have been as applicable *before* the creation of man as it is now. This proves that it is based upon a general law, and is not the effect of any special application. Not only have

many good men thoroughly believed in and admired the doctrine that, in the vegetable world at least, most things were created with special reference to man's requirements; they have even gone so far as to imagine that all plants which are evidently baneful must be due to some such moral agency as that which was included in the "Fall." Thorns, thistles, poisonous plants, parasites, &c., are not unfrequently referred to by many writers unskilled in natural science as proofs of some such disarrangement of the vegetable kingdom. A good deal of such botanical philosophy, it must be granted, is based on too literal an interpretation of the second chapter in Genesis, where "thorns and thistles" are connected with the primal disobedience. The geologist knows that thorny plants are met with in the fossil state; and that their present distribution and abundance bears no reference whatever to the density of human population, as it would do if *thorns* were botanical inflictions. He can further point to flowers which had brilliant colours that lived even in the Cretaceous period, long before the appearance of man. Dr. McCosh, in his 'Typical Forms and Special Ends,' quotes a paragraph which Brongniart made in 1849, that "a remarkable character of the floras of the Eocene, Miocene, and Pliocene epochs—which immediately preceded man's epoch—is the absence of the most numerous and most characteristic families of the *Gamopetalæ*."

The inference is that as these plants bear some

of the most showy flowers, there is a designed intention between their non-appearance in the above epochs, and the non-appearance of man. In geology, however, it is always unsafe to reason from such negative arguments as the mere absence of certain fossils from any deposit. We are enabled to examine such a very little proportion of any stratum for fossils that new forms may be discovered at any time which will invalidate conclusions hastily drawn from their previous non-discovery. This has proved the case with the Miocene flora of Switzerland, so exhaustively worked by Prof. Heer, of Zurich. The list of fossil plants found in the Œningen beds includes genera which bear brilliant and showy flowers, such as the *Magnolias* and *Poranas*. Dr. McCosh distinctly states in the chapter from which we have already quoted, "that just about the time when there appeared an eye to receive and convey the impressions of beauty, and an intellect to derive satisfaction from the contemplation of such, then it was that the most highly adorned productions of Flora's kingdom were called into existence." If Dr. McCosh means that the flora of the world is more various and beautiful now than it ever was before, we quite agree with him; but the reasons for this are certainly due to other causes than the narrow ones he assigns. Some excuse must be made for modern naturalists often feeling irritated when they meet with the numerous dogmatic conclusions which theologians who have

hastily studied natural history deal forth in the most prodigal manner. Thus Dr. McCosh affirms "that plants were *meant* not only to furnish food to the animal creation, but were *intended* to afford them pleasure by their tastes and by their perfumes." The narrowness of these short-sighted conclusions does more harm to theology than good. For if only some of the facts on which they are based afterwards turn out to be spurious, the arguments based on them fall like a house of cards.

We contend that the teleological argument must not be narrowed to man's needs or pleasures. It should be as comprehensive as the organic world itself, and take note not only of the "very hairs of our heads," but also of the "two sparrows which are sold for a farthing!" The effect of the evolution theory, properly understood, is to magnify the Divine care for all that hath enjoyed the breath of life since vital force was modified from the physical. The fault of the old teleological arguments in theology has been to make man the pivot around which the whole creation revolves. Everything has been studied only in reference to him, and was supposed to be designed in some way for his benefit or pleasure. These views made it impossible to understand why there should be such dead worlds as the moon; or why earthquakes and volcanoes, tempests and hurricanes, carnivorous animals and raptorial birds, poisonous plants and mildew fungi, should appear on our own. The issue of thus regarding man

as the main end of creation has been injurious to himself, for it has made him more reckless in his destruction of the lives of animals lower in organization, insomuch that one of his chief sports is their slaughter! We constantly hear such ignorant questions as "What good is it?" applied both to animals and plants. Were the querist to put such a question to himself, he would often find it much more difficult to answer! The tendency of the idea that all things were created solely for the use and enjoyment of man is therefore likely to brutalize and hinder the development of man's highest faculties.

The magnificent unity of all creation, physical and organic, past and present, which the modern philosophy of evolution is rapidly presenting to the human mind, cannot fail to lift the teleological argument to a higher platform. Those who contend that flowers, and especially the most beautiful and sweetly perfumed of their kinds, were intended to administer to human appetite alone, should be somewhat acquainted with the distribution of flowers, as well as with their geological antiquity. The fact that flowers like those now living appeared before man was created, so far weakens the general argument that flowers were formed to delight him. But we have only to reflect that the hundreds of species of our common British wild flowers which carpet our June meadows, or upholster our green lanes, are little heeded by the majority of people; and we see that if they were

placed there to administer to human pleasure alone, their creation would have been partially fruitless. Some of the loveliest of our native plants bloom where no eyes can behold them, except those of the eagle; for our Alpine flowers are silently and solemnly expending their beauty in lonely spots most distant from the busy haunts of men. The most gorgeous of exotic plants blossom in lands where mankind are little above the brute in intellectual development, and care as little as the animals for the floral loveliness so lavishly surrounding them. Not a few uninhabited islands, when discovered, have been found literal paradises of flowers. Or we have instances, such as that so vividly described by Charles Kingsley in 'At Last,' where numerous tropical climbing plants in their haste to reach the light and heat, twist themselves around the tall forest trees so as almost to strangle them, scarcely putting out a leaf until they reach the level greenery of the tree-tops, two hundred feet above the ground, and then they burst forth into such a sea of floral colour and perfume as cannot be described. But all this beauty is lost to mankind beneath! To perceive it and enjoy it, he would have to avail himself of some such aid as that obtainable by a balloon. Again, the older theory fails quite as much to account for the unequal geographical distribution of flowers, as it does for their geological antiquity. It does not say why islands like Juan Fernandez have an abundance of large and beautiful flowers, and New Zealand

chiefly flowers which are inconspicuous. It offers no explanation for the masses of colour which literally burst forth on the edges of glaciers, or as soon as the summer's sun has peeled off the winter's snow from the ground in Arctic regions. It is contented to deal in weak platitudes about "special design," when a little examination cannot fail to show that if the chief *raison d'être* of flowers be to delight the human eye and administer to the human appetite, it is almost a total failure!

Mary Howitt expresses the more poetic feelings of this class of thinkers when she asks of flowers in one of her poems—

> "Wherefore, wherefore were they made,
> Or wherefore had they birth?"

and she goes on to answer, after the manner we have been describing—

> "To comfort man, to whisper hope,
> Whene'er his faith is dim,
> That He who careth for the flowers,
> Will much more care for him."

The new philosophy of flowers in no way prevents poetic and religious minds deriving pleasure and profit from these lovely objects. All that has been said of flowers, by the best writers of all countries and ages, remains as it did before. We contend only against the narrowness of the idea that flowers were specially created to delight mankind. With the larger

and deeper significance they now possess, they appeal to us as they did to Wordsworth, to whom

> "The meanest flower that blows can give
> Thoughts that do often lie too deep for tears."

Much religious delight and comfort may be obtained by cultivating a love of flowers ; but this desired result need not interfere with a true knowledge of the functions and relationships of plants. Some writers have not hesitated to declare, in reply to the query why beautiful flowers bloom where no human eyes can behold them, that God created them for His own pleasure and delight! This idea is little better than immoral in its religious tendency, and exhibits Deity as deriving the same kind of pleasure as would be enjoyed by some ingenious child! Nay, whilst the child would obtain delight by the indulgence of his natural contriving faculties, without any regard for the object after its completion, this notion represents God as creating objects so that He might Himself afterwards enjoy them! The narrowness of this idea may be safely left to wither away from its own want of sustenance. It certainly cannot be accepted as a scientific explanation of the absence of mankind where flowers often blossom most freely. We question whether it is within the rightful province of any human being to define what is the peculiar pleasure in which the Deity delights.

A large number of plants are not useful to man

until they are cultivated, and the number of these is constantly being increased. Not a few are by nature actually *poisonous*, and yet human ingenuity has been able to deflect or neutralize their poisonous character. Of such plants we may mention the common celery, whose poisonous nature, developed by the action of light, becomes inocuous by earthing up the edible leaf-stalks. In the manihot we have a most virulently poisonous plant, whose root nevertheless yields the well-known *tapioca*. In this case the poison is got rid of by the preparation through which the tapioca undergoes before it comes into the market. A good many other examples might be adduced where baneful plants have been converted, in whole or part, into beneficial ones. If there be some mystery attached to the existence of poisonous plants which causes people to regard their existence as a penal infliction, how is it that the most dangerous of them can, by a little ingenuity, be converted into useful species? A good deal has been made by some writers of the larger number of beneficial plants now in existence than in any previous geological period. This argument is of a very negative character, for no botanist can deny that it is possible mankind would have been able so to cultivate some of the extinct kinds as to have derived benefit from them. Indeed, we know that many edible genera have been in existence throughout the entire Tertiary epoch. The striking difference between the same species when wild and

cultivated (as in the case of the common cabbage) is so great, that it ought to deter us from forming hasty conclusions as to which are and which are not the best kinds of plants to surround mankind with.

Such have been some of the leading views obtaining in what we have chosen to call the old philosophy of flowers. Its weakest place is in regarding the existence of plants as having reference only to man. In the new philosophy of flowers, which has gradually been gaining ground for half-a-dozen years past, whilst none of the benefits or dangers to man accruing from plants is denied, it is contended that these are but secondary in their real design. It endeavours to show that all the qualities possessed by plants of every description, flowering and flowerless, but especially the former, are just those which are of the greatest importance to plants themselves. Thus most flowers require crossing, and the floral machinery of even our common British wild flowers is of the most unlooked-for and complex description, usually designed to *prevent* self-fertilization, and encourage or ensure *crossing*. Among some of the chief of these devices may be mentioned the following: absolute barrenness when the pistil is fertilized by the pollen of the adjacent stamens; pistils ripening before the stamens, or stamens before the pistil; *dimorphism* and *trimorphism*, or flowers possessing pistils and stamens of two and three lengths, all intended for the special purpose of crossing; the existence of *monœcious*

and *diœcious* flowers, or those in which we have staminate and pistillate flowers on the same plant, but with the pistils and stamens separated from one another, and those in which one plant bears staminate flowers only, and the other pistillate flowers. Most of these contrivances are not of a nature to invite attention; and some of them have escaped the notice of botanists for years, or had been remarked without being understood. We can therefore readily understand why they should be passed over by those who are totally ignorant of botanical structures. And yet it is these very organs and their arrangement, on which the perpetuity of the species depends. Those which constitute what are popularly called "flowers," such as the attractive petals, are of secondary importance; and colour is quite absent in the majority of species. The qualities of flowers which recommend them most to poetical minds are their forms, colours, and perfumes. Poems innumerable have been suggested by these qualities, but rarely a line has referred to the much more important stamens and pistils, which really carry on the important work of reproduction!

The colours and perfumes, and in many instances even the *shapes*, of flowers have reference *only* to the visits of Insects. And in proportion to the brilliancy or size of the corolla, or the sweetness of the perfume, is the necessity of the plants possessing them to be crossed. On the other hand, inconspicuous flowers are either self-fertilized, or only occasionally require

to be crossed; whilst the largest number of flowers, such as the grasses, sedges, rushes, &c., have no corolla at all, and do not require insect aid to carry the pollen from plant to plant, so as to beneficially cross them. Modern botanists find it comparatively easy to group all plants into two great divisions—those crossed or fertilized by insects, and those by the wind. The terms *entomophilous* and *anemophilous* are applied respectively to these two classes. That insects of all kinds have keen eyes for colour, everybody is aware who has witnessed them pausing in their flight to visit flowers whose brilliant hues had attracted them. Every cottager who has hung the gaudy-coloured paper "fly-cages" in his room, to prevent his clean whitewashed roof and walls from being dirtied by the common house-flies, has practically availed himself of the attraction which bright colours have for even these non-flower-loving insects. Perfumes are hardly less desirable, as all will admit who have sat under the linden trees some early July day, and heard the loud and uninterrupted hum of insect life above him, attracted by the sweet perfumes of the inconspicuous lime flowers. It is these qualities of colour and perfume which have caused the objects possessing them to be termed *flowers* above any other.

Let us turn to the grasses—their number is exceedingly great, and when we add to them the sedges and rushes, it will almost equal the lists of the petalled

flowers. But many of our shrubs and trees, such as the hazel, elm, oak, birch, alder, pines, &c., have not brilliant flowers—they are crossed by wind agency; and therefore belong to the *anemophilous* group. To these we must add such plants as the nettles, the hop, dog's mercury, docks, goose-foot, plantains, and many others, which are chiefly crossed by the wind carrying pollen from one individual plant to another; and we conclude that the number even of British flowers not *popularly* deemed such, exceed those which have appropriated the name.

The differentiation between insect-crossed and wind-crossed flowers is not limited to their external appearance. Anyone who is aware of the number of eyes possessed by insects, knows that their power of vision is perhaps unequalled in the entire animal world. The sense of smell, also, is so exceedingly highly developed, especially in the butterflies and moths (or *lepidoptera*), that some naturalists have regarded it as almost equivalent to a *sixth* sense; although they are unable properly to locate that sense, and therefore provisionally place it in the antennæ. Many male butterflies and moths will travel great distances to visit the imprisoned virgin females which an entomologist, aware of the fact, may have with him. This keen and subtle sense has caused much comment, and it can hardly be assigned to a development of any other than that of *smell*. Some entomologists have expressed their belief that insects

possess even a *language of scent!* We see, therefore, how directly flowers possessing sweet perfumes, must appeal to insects so acutely endowed. The wind, however, is an inorganic force, possessed of no appreciation of qualities. Colour and perfume in the flowers dependent on the wind for crossing would be absolutely thrown away. And so we never find these desirable attractions in wind-fertilized flowers, much as their presence might delight the eyes of man. It is required that the stamens of such plants should be long and pendant, in order to be easily shaken by the wind, as we find them in the grasses and in the catkins of hazel, poplar, birch, &c., and also that they should produce an abundance of pollen, so that the wind may be charged with it. Indeed, so great is the abundance of pollen secreted and discharged by the largest number of those wind-crossed plants the grasses, that we have the peculiar complaint known as the "hay-fever" experienced by people of very sensitive nostrils! In this case we can hardly say that the flowers of grasses were created to produce either æsthetic or sensual delight!

Again, to such an extreme is the division between wind- and insect-fertilized flowers carried out, that the microscopist can without much difficulty assign even pollen-grains to one or the other of these groups. Thus, the pollen usually produced by *entomophilous*, or insect-loving plants, have their surfaces roughened over with minute points or other means of readily

attaching them to the hairy bodies of insects. On the other hand, the pollen-grains of *anemophilous*, or wind-fertilized plants, are exceedingly light, usually round or lenticular, and expose as much surface as possible to the force of the wind which blows them about.

We have presented to us by the new philosophy an unlooked-for and direct connection between two important groups of organic objects, insects and flowers. That all the living things in the world are somehow related to each other's needs has long been an article of popular scientific faith, but the development of this inter-relationship requires much toil and patience. The intimate relations between flowers and insects, however, we may regard as an instalment of the knowledge which subsequent years will adduce of all organic objects. Flowers, with their pollen, and still more, their stores of *nectar* or honey often secreted in the most wonderful manner (and not unfrequently by aborted organs which originally did other floral work), are evidently dependent on insects. Their colours are related to them; for instance, *white* or light-yellow flowers usually open at night, and throw out their perfumes most powerfully then, so as to attract moths, whose sight, active though it be, could not well perceive *colours* in the dark; whereas white would be fairly visible, especially if there existed perfumes to attract them to it, as in the case of the white campion (*Lychnis vespertina*). Such flowers as the honeysuckle

have long tubes containing honey at their bases, which can only be reached by such insects as the *sphinxes* or hawk-moths. The latter have not only long probosces, but slender bodies and hawk-like wings, which enable them to hover in one position over a flower whilst they suck its nectar. Darwin has shown that in some instances the relationship between certain insects and certain plants has been so narrowed that if the insects were absent from any locality the plants necessarily would be. In the orchids, British and exotic, the dependency upon insect fertilization is very certain, and the number of contrivances existing in the different genera would delight the most skilful of human mechanicians with their complexity and variety. We are not here speaking, however, of limited and special adaptations, but of the broad fact that all flowers possessing gay or coloured petals and sweet perfumes, own them because they are serviceable. Without them, such plants could not perpetuate their kind. They would not be crossed with pollen, would therefore produce no seed, and consequently would become extinct. Perhaps among the reasons which have caused some of the genera of flowers whose remains we find in various of the Tertiary geological formations to become extinct is, that physical geographical changes may have removed the insect life which was necessary to cross them. We know that drainage will affect the distribution of the butterfly orchis, because it affects the insects which alone can fertilize this

peculiar kind of flowers. And it is a remarkable fact, that the smoke and chemical odours which surcharge the atmosphere of such of our large towns as Manchester, Leeds, and Derby, by causing certain kinds of insects to keep away, have indirectly but positively made it impossible for numbers of wild plants formerly included in the local floras, to perpetuate themselves now!

Although the geological record is undoubtedly "imperfect," there can be no question that the number of fossil insects (which we know frequent flowers and are attracted by them) is greater as we approach the present epoch. *Lepidoptera* have been, for certain, found fossilized for the first time in the Tertiary strata. Hence, with the number of flower-loving insects, the number of attractive and perfumed plants has increased. The maximum of the latter—fortunately, perhaps *designedly*—occurs in the human epoch. But the agencies which have developed their beauty are unquestionably insects; and the flaunting of these gay colours, sweet perfumes, and more practical honeyed nectaries is intended in the first instance, not for man, but for insects! This at once accounts for the existence of flowers before the creation of humankind, as well as for their geographical distribution where men's eyes cannot behold them, or if they do, cannot appreciate them.

Such a special connection between one group of the animal and one of the vegetable worlds, we affirm,

need not interfere with man's enjoyment of the presence of either. It may operate as a check to his self-conceit to feel that flowers have not been primarily intended for himself; but, if his be a well-regulated mind, the marvellous inter-relationship between insects and flowers which science has thus brought to light, will throw an additional halo of poetic interest over these unconscious agents, which, acting through blind instincts, have made the world more beautiful for those who can admire it.

CHAPTER II.

THE GEOLOGICAL ANTIQUITY OF FLOWERS AND INSECTS.

ALL naturalists are now agreed that the animal and vegetable kingdoms have been correlated to each other ever since life first appeared upon the earth. From the lowliest to the most complex types, this mutual relationship has bound them together into an organic whole. The "records of the rocks," however, are not complete. The story of the life of the globe is exceedingly fragmentary. If the geological record is imperfect as regards the *animal* life which has peopled our globe during past ages, none will be surprised it should be considerably more so as regards extinct *vegetable* types. The chances are infinitely against the sufficient preservation of the latter to enable modern botanists correctly to make out their relationships. The earliest plants were formed of loose vascular and cellular tissues, which readily decomposed, and were therefore difficult of fossilization. Plants do not possess the hard and comparatively indestructible parts which the majority of animals have, such as teeth, bones, tests, and shells. Only a few plants have external substances capable of resisting decomposition,

but such species rank low in the scale of classification, as in the case of the *Diatomaceæ*, which possess siliceous frustules or valves. The horsetails (*Equisetaceæ*) are remarkable among plants by the large quantity of silica which enters into the tissue of their exterior; and in this respect they resemble many of the grasses, notably such gigantic species as the bamboo.

With the exception of the *Algæ*, or sea-weeds, plants are chiefly terrestrial in their habits. Even those flowering plants we call aquatic, only grow at the margins of the land or in shallow water. The number of true flowering plants, such as *Ruppia* and *Zostera*, which live in brackish or salt water, is very few. Consequently geologists are dependent for the preservation of plants upon fewer physical possibilities than those which allowed animal remains to be fossilized. Only where some extensive lake has had sediments quietly forming along its bottom, or in the estuary of some large and not too turbulent river, has it been possible for plants to be mineralized; and it is in lacustrine and estuarine deposits that we find vegetation most perfectly and abundantly fossilized. On the other hand, every geological formation abounds more or less in animal remains; they are chiefly those of marine species which lived in the seas along whose floors the rocks were originally laid down in the sedimentary state. In estuarine and lacustrine strata we meet with the largest number of remains of land animals. Their carcases have been brought down by

streams and rivers. The proportion of land animals thus preserved, both vertebrate and such invertebrate forms as insects, bears a certain proportion to the number of true terrestrial plants which have also been fossilized.

If therefore the geological record is meagre as regards fossil animals, most of which were marine, it must necessarily be so as regards plants. As to their bearing on the doctrine of evolution, less than ten years ago some of our best naturalists held that fossil animal remains were neutral. So little dependence could be placed on any inference drawn from their geological distribution, owing to the possibility of their unexpectedly being found in other strata than those to which it was supposed they had been limited, that philosophical naturalists preferred to regard palæontological evidence for the time as *nil*. But year after year has witnessed the discovery of new animal forms in strata of all ages, and in different parts of the world, and now the most stubborn opponent of evolution is obliged to acknowledge that the balance of evidence from fossil remains is becoming every day larger in favour of the new philosophy.

Much the same may be said of fossil botany. Owing to the value of mineralized vegetation when it assumes the shape of coal, the formations bearing it have been better studied and explored than any other, so that the chances of finding new vegetable forms have been greatly increased. But we have sometimes

1. **SNAKESHEAD LILY.** *Fritillaria meleagris.* 2. **TURK'S CAP LILY.** *Lilium martagon.*
3. **FLOWERING RUSH.** *Butomus umbellatus.* 4. **BEE ORCHIS.** *Ophrys apifera.*

to skip formation after formation before we can take up any inference drawn from the occurrence of fossil land plants, and we are often surprised by the contrasts between floras thus separated by extensive epochs. For instance, after the abundant flora of the Coal measures, we meet with little until we come to the Upper Cretaceous, Eocene, and Miocene formations. Here and there in the Lias, some parts of the Oolite, and also in the Cretaceous rocks, we come upon local floras, some of which, as in the case of the Upper Cretaceous floras, had a very extensive geographical distribution, so that any inferences drawn from their occurrence are much safer than if we had met with a fossil flora in one locality only. Whereas in the animal remains of the successive formations we can witness group after group of marine organisms making their appearance and becoming extinct, the story of the vegetable life of the globe is interrupted by enormous periods of time. This is due to the fact that the greatest number of the rocks with which geologists are best acquainted were formed in seas at some distance from land, where it was impossible for land vegetation to be carried without its distinguishing characters being destroyed.

Notwithstanding this botanical "imperfection," there are certain broad and unquestionable principles which geologists can depend upon in the succession both of animal and vegetable types. Thus, we find that the *simplest* forms appear in the oldest formations, and

the most complex and highly organized in the latest. No investigation appears likely to disprove this most important fact. Again, as regards animals particularly, and, as far as can be ascertained, with plants also, the most *generalized* of organized objects precede the *specialized* species. If we had as good means of identifying plants from fragments as we have in the case of the higher animals, there can be little doubt we should find the same truth holding equally good in the vegetable kingdom. Modern naturalists have made some important discoveries by the light of embryology—that is, of the probable descent of any species by tracing the successive changes which it may pass through as an embryo. In this way it is found that the embryo of a mammal passes through an enormous number of stages, from those representing single-celled infusorial animalcules upwards and onwards through others corresponding to fish, amphibian, reptile, and bird. These embryonic stages are a kind of condensed evolution, taking place and succeeding each other in a few months instead of in millions of years, and occurring in the life history of one animal instead of an incalculable series. Embryology therefore is regarded as illustrative of palæontological evolution.

But here again animal structures give a greater advantage to the student of their history and relationships than plants. The latter have fewer embryological stages through which we can trace their

probable lines of descent. This has been attempted by a few English and German naturalists, and with considerable success, but the subject remains almost unworked. The most suggestive probabilities as to the origin of some of the leading orders of flowering plants come from a quite unexpected quarter, namely, their "monstrosities" or teratology. Thus, we find that frequently the *abnormal* conditions or monstrosities of one order of plants correspond to and assume many of the characters distinctive of another order. In this way it is possible some orders may have arisen through adventitious changes in structure brought about by changes in the biological and physical surroundings, such as those of insects, climate, moisture, and height above the sea-level.

The correspondence in the mode of succession of animal and vegetable remains, as everywhere revealed by the study of geology, renders it very probable that we have deduced their true order of appearance on our globe. Such terms as were used by the older geologists, as the "age of fish," the "age of reptiles," and "age of mammals," roughly express this method of succession. And beyond modifications in the hard and fast lines where they made these animals to come in or disappear, nothing has been discovered to interfere with the classification. Corresponding to these was the classification of the vegetable kingdom, based on fossil remains, founded by Brongniart many years ago, of the "age of acrogens" (or ferns), "age of

gymnosperms" (or conifers), and of "angiosperms" (true-seeding plants). In both kingdoms, animal and vegetable, there is the strongest evidence—evidence which every new discovery strengthens—that the lower preceded the higher, and the general the special forms.

Brongniart's simple classification of the geological order of succession of the three most prominent of vegetable types upon the earth, ought by no means to lead the student to infer that during the "age of acrogens" or ferns, there were no conifers, or that, when the "age of gymnosperms" prevailed, there existed no true-seeding or angiospermous plants. The classification indicates only the prevailing groups of vegetation. These can be again divided, so that we find the order of classification corresponding to that of palæontological succession. Thus, up to the conclusion of the Silurian period, sea-weeds or *algæ* were the dominant types of vegetation; from the upper Silurian to mid-Carboniferous times, ferns and club-mosses (*Lycopodiaceæ*) were most abundant. In the Permian and Triassic period coniferous trees were in the ascendency; then follow monocotyledonous plants, such as palms and grasses in the Oolite, and true flower-bearing plants in the Lower and Upper Cretaceous; with abundance of them in the Eocene, a preponderance of them in the Miocene strata, and so onwards to our own time. Even among the true flower-bearing or phanerogamous plants, we find that the

monocotyledonous preceded the dicotyledonous, that the wind-fertilized groups (*anemophilous*) of dicotyledons appeared before the insect-fertilized (*entomophilous*), certainly as orderly as the acrogens came before the gymnosperms. For the occurrence of a few insect-fertilized plants among the first dicotyledonous flora, no more invalidates this conclusion than does the fact that we find coniferous trees in the Devonian rocks interfere with their existing in the true "age of acrogens."

Botanists are now convinced that the colours of petalled or perianthed flowers exist, in the first place, because they are useful to plants in attracting insects; and that the visits of insects thus secured cause pollen to be carried from one plant to another, and so produce the degree of crossing which is beneficial. It has been found that the size and colour of the corollas of flowers (as in the geraniums), the intensity of their perfumes, or the more practical larger amount of honey which may be secreted in their nectaries, are always proportioned to the needs of the flowers to be crossed by pollen other than their own. So necessary is this crossing in some instances that the pistil of a flower is as barren when dusted with pollen from its own stamens as if it had been with pollen from an altogether different species. It had long been acknowledged in a general way that flowers were necessary to insects, but it is only within the last few years it has been discovered that insects are quite as

necessary to flowers. With the exception of accidental crossing, which may result from such fringe-winged insects as the minute little *Thrips*, which may be seen in most English flowers, the insects which can fertilize or cross different flowers, so as to make their visits important and serviceable, are limited to two or three orders. There are twelve orders of insects now recognized by zoologists; but of these only *one* is absolutely specially adapted to flowers. This is the order *Lepidoptera*, a peculiar flower-haunting group all over the world, both in the day-flying species called butterflies, and the night-flying species known as moths. Their mouths are in the shape of a trunk or proboscis, which does not allow them to suck food except in a fluid state, such as that in which we find the natural honey of plants. From this universal fact of the *Lepidoptera* being suctorial, there is only one exception in the case of the few curious moths in Australia (*Ophideres*), which have boring or terebrant mouths; thus linking the *Lepidoptera* with other orders of insects. Next to the *Lepidoptera*, in its importance to flowers as an order, is the *Hymenoptera*, of which, however, only the bees are purely flower-frequenters; a good many members of their order are even disadvantageous to flowers. Among the latter we may instance numerous species of ants, whose fondness for the honey secreted by flowers induces them to climb the stems of plants for the purpose of obtaining it. But as these insects are *wingless* (except a par-

ticular set at a certain time of the year, when flowers have nearly all bloomed), and as their bodies are glossy and bare of the hairy covering which in butterflies, moths, and bees enables the pollen to stick to the body, it follows that ants cannot be serviceable to flowers in crossing them; whilst if they steal the honey offered as a reward to serviceable insects, they are so far actually enemies. It is to protect flowers against such predatory excursions as those made by vigilant ants, that their stems are covered with hairs and prickles, or gummy with viscid secretions, as in the case of Spanish catchfly (*Silene otites*) and others. Some of the *Coleoptera* or beetles, such as the rose-chafers, and various small species, are of advantage to flowers by carrying away the pollen which attaches itself to the under side of their bodies during their slow and sleepy foraging in the bosoms of flowers. Many *diptera* are also useful to plants in crossing them, for some are known to be pollen-feeders. But enough has been said to prove that the *Lepidoptera* first, and such specialized forms as the bees among the *Hymenoptera* second, are those members of the insect world on which large and attractive flowers are most dependable for effectually crossing them; although there is no doubt that dipterous flies are also largely engaged in crossing the smaller flowers.

Now, if among the vegetable productions of the globe those plants which bear conspicuous and attractive flowers are the latest introduced (as we have

seen they are, the *anemophilous* group preceding the *entomophilous*), then, as the *Lepidoptera* are so absolutely necessary to the perfect crossing of plants, they ought to make their appearance in similar order. That is to say, if true flowers are the latest of all the developments of the vegetable world, butterflies and moths ought to be the latest evolved among the insect tribes. Remains of insects have been found fossilized in deposits as ancient as those of the Devonian period, and from that time onwards to our own, under conditions which would have admitted the equal preservation of *Lepidoptera*, had those insects been then in existence. We do not wish to assert that in spite of their gay colours and attractive appearance, we regard butterflies and moths as the highest organized of insects. On the contrary, bees, ants, and wasps among the *Hymenoptera*, and termites, or white ants, among the *Neuroptera*, by their subtle display of instinct, their knowledge of the division of labour, and the general mode in which they conduct the affairs of the hives or republics in which most of them live, recommend themselves to our notice as cerebrally the higher endowed of all forms of animal life; and, in proportion to their size, perhaps even the highest, not excluding man himself. But the *Neuroptera* and *Hymenoptera* were in existence ages before the appearance of moths and butterflies, although it is not until the Tertiary period that we find them fossilized in such specific forms (termites and ants) as leads us to

believe their marvellous instincts had then been established.

We have seen it is possible to trace in a few words the general order of succession of the leading types of animals, and also of plants. Lubbock and other philosophical entomologists are of the belief that the various orders of insects came into existence, at different periods, something as follows:—*Orthoptera* and *Neuroptera* in the Devonian epoch; *Coleoptera* during the Carboniferous; *Hymenoptera*, *Hemiptera*, and *Diptera* during the Oolitic and Cretaceous periods; and *Lepidoptera* not until Tertiary times set in. The remains of a supposed fossil butterfly have been found in the English oolites, and named by Mr. Butler *Palæontina oolitica;* but the lepidopterous character of the single wing thus named is doubted by Mr. S. Scudder in his work on fossil butterflies. Two other supposed Secondary butterflies have been criticised by the latter author, one of which specimens he has personally examined, and this he declares belongs to another order; and the other, which he has not seen, he does not think is lepidopterous. This examination leaves Lubbock's generalization true, for the present, that the *Lepidoptera* only appear in Tertiary strata. We see no reason, however, why they should not have appeared earlier, say at the beginning of the Cretaceous epoch, when true flower-bearing plants first made their appearance, although the first flower may have blossomed more for *Hymenoptera* than *Lepid-*

optera; and, indeed, the fact that the first flowers were polypetalous rather than gamopetalous—that is, had corollas made up of separate petals, rather than of the petals being joined together, as we find them in the common blue-bell (*Campanula*)—is an indication that gamopetalous flowers could only be formed when there were insects with probosces long enough to be thrust down to the nectaries at their bases, as we find them in butterflies and moths.

Thus we see that there is a broad parallelism between the appearance of the more differentiated types of the vegetable kingdom, and the development or appearance of the orders of insects. Instead of the appearance of a new order, the differentiation may sometimes have been accompanied by such specialization of a large group as the bees among *Hymenoptera*. Mr. H. Goss has published three important papers on the insect fauna of the Primary, Secondary, and Tertiary periods, in which he has given the proportion of species. Of these we find the *Coleoptera* or beetle family best represented. It is one of the most extensive in its geographical distribution—a fact which always indicates the antiquity of organic forms, as it proves they were spread before those physical geographical changes occurred which give the surface of the earth some of its present features. Among the beetles, also, we find a notable differentiation; their genera are adapted to almost every habit of life, aquatic, subterranean, and terrestrial. They are aborted as

well as developed, as in the case of the glow-worm. They live on carrion, fungi, pollen, nectar, wood, leaves, and other organic substances, and have their structures modified accordingly. Hence we cannot be surprised the *Coleoptera* seem to have been from the first a dominant order, seeing how useful beetles have made themselves in the economy of the globe. Perhaps the endurability of their hard wing-cases (*elytræ*) has frequently enabled them to be fossilized when other insects would have been decomposed, and thus caused them to appear numerically more abundant than contemporary orders.

We find the general distribution of insects, in geological time, to be in the order we should expect from what has already been said. The oldest fossil insect is termed by Nicholson *pseudo-neuropterous*—a name which indicates its generalized character. This occurs in the Devonian rocks of North America, but the large size of wing of one of the fossil species (indicating an expanse of five inches) leads us to infer that these Devonian forms cannot be the oldest of winged insects. Mr. Scudder regards this earliest known insect as a "synthetic type"—that is, one which combines peculiarities of structure now distributed and specialized in different groups. In the Carboniferous rocks many species of fossil insects have been met with. Among the *Neuroptera* we have a member of the *Ephemeridæ* or "May-flies," larger than any now known, having an expanse of seven inches of wing.

These are insects which pass the first stages of their existence as *aquatic* larvæ—a singular fact in the history of insect evolution. The *Orthoptera* are represented by very generalized forms of cockroaches, crickets, and locusts. Beetles, however, are not as yet so abundantly preserved.

In the Secondary rocks large numbers of fossil insects have been found, and here beetles take the leading place. One great storehouse for them is the Lias beds at Schambelen, Switzerland. In England the Rhetic beds have yielded a rich harvest, as may be seen by a reference to the work on British Fossil Insects by the Rev. James Brodie. The Purbeck beds are also locally productive of many fossil species. No *Hymenoptera* have yet been found in the Rhetic beds, but 29 species of *Coleoptera*, 12 of *Neuroptera*, 9 *Hemiptera*, and 7 *Orthoptera* from these strata have been described. Two species of beetles have been found fossilized in the Swiss Trias. Professor Heer has discovered in the Liassic rocks of Schambelen no fewer than 143 specimens of fossil insects, which he has distributed as follows: *Coleoptera* 116 species, *Hemiptera* 12, *Hymenoptera* 1. The fossil beetles had even then been specialized into carnivorous types: others were leaf-feeding beetles. Some evidently lived on decaying wood; but as yet there were none which are now known to haunt flowers.

In the Stonesfield slate of England various fossil insects have been discovered. These are represented

by large species of *Neuroptera*, such as dragon-flies, various well-differentiated genera of *Coleoptera*, already adapted to different kinds of food and habits of life; but none of them are flower-frequenters. It was in this bed that the supposed fossil butterfly called *Palæontina oolitica* was met with. If this be a true butterfly there must have existed flowers at the time when the Stonesfield slate was formed, according to the theory that flowers and lepidoptera go together. Scudder, however, as we have seen, holds that *Palæontina* was not a butterfly but a *Cicadeous* insect. The Purbeck beds were formed in a large lake, and under conditions such as are favourable to the preservation of insects; and accordingly large numbers have been obtained from this interesting formation. The orders *Diptera*, *Orthoptera*, *Neuroptera*, and *Coleoptera* are abundantly represented by fossil gnats, cockroaches, dragon-flies, and huge ants allied to exotic genera. Out of sixty-four species described, the beetles number eighteen. The hemipterous insects follow next, with fourteen species; the *Diptera* with thirteen, and the *Orthoptera* with ten. The beetles are chiefly herbivorous kinds.

When we come to the Tertiary strata undoubted lepidoptera make their appearance. There is no longer any zoological doubt as to what they are. But this is the period when true flowers began to be abundant, and therefore it is significant that we should find specialized flower-loving insects appearing at the same

time. As a rich fossil flora, containing true flowers, has been found in formations as old as the Lower Cretaceous in Greenland, it is possible that lepidoptera appeared before the Eocene period. Nine species of fossil butterflies are found in strata of the latter age at Aix in Provence. The Miocene strata of Switzerland have yielded an immense number of species of fossil insects, which have been described by Professor Heer. In beds of the same age at Radoboj in Croatia, three species of butterflies have been found; one of them singularly allied to a living Indian species. In this formation the *Hymenoptera* are very abundant. From the Swiss Miocene beds at Œningen Professor Heer has obtained nearly nine hundred species of fossil insects, out of which the *Coleoptera* number no less than five hundred and eighteen. Not only do we find these Miocene beetles differentiated and adapted to all the habits of life which their Oolitic antecedents had already possessed, but for the first time we come across true *flower-haunting* beetles, belonging to groups actually specialized in our own day to particular genera of flowers. So striking is this that Professor Heer infers the existence of such flowers (although they have not as yet been found) during the Miocene epoch. The fossil *Hymenoptera* of Œningen number *eighty* species, and among these are those highly specialized forms, such as bees, which are always associated with flowers. Three species of butterflies are all which have as yet been recognized.

It would seem probable, therefore, that bees appeared before butterflies, and obtained their remarkable specialization by being adapted to the earliest of the flowering plants.

Near the White and Green Rivers, bordering on the territories of Utah and Colorado, an immense Tertiary deposit has been explored by the United States surveyors. Its shales have been found crowded in places with insect remains, including even the larvæ. One species of *Thrips* has been found whose minute fringed wings, characteristic of its order, are visible under the microscope. Fossil ants occur here, so that their peculiar specialization had already been effected. Only one species of moth, however, has hitherto been found out of the sixty or seventy fossil insects described.

Later Tertiary beds always contain fossil insects where the conditions are favourable to their preservation; but it would appear as if all the great orders had assumed their modern distinctiveness before the close of the Miocene period. What has since occurred has chiefly been their changed geographical distribution, and the breaking up and differentiating of two of the orders, *Hymenoptera* and *Lepidoptera*, so as to adapt many of the species of each to the most abundant or most frequented of the flowers where such insects have been distributed.

Thus we see that a comparison of the order in which insects have appeared would lead us to infer the

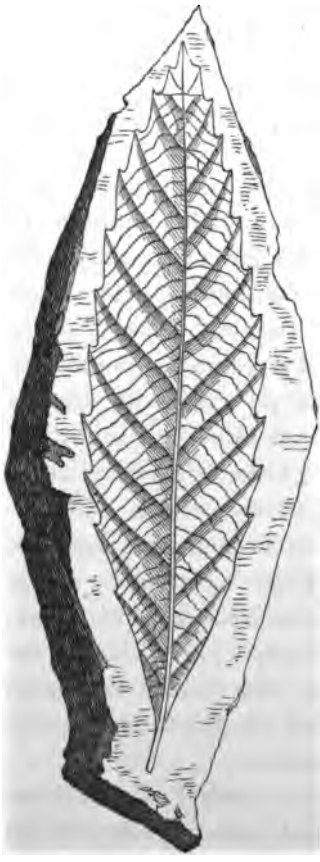
absence of true flowers until the later geological epochs. A parallel development has taken place in insects and flowers during geological times, so as to slowly and mutually adapt each to the other. The order in which the various families of flowering plants have appeared bears a relation to that in which the different orders of insects have succeeded each other. Thus we have first the conifers and cycads, wind-fertilized plants, producing a superabundance of pollen so that some of it could surely take effect. The grasses and sedges probably appeared during the Triassic, Liassic, and Oolitic periods, although in no very great abundance or variety, or we should have more fossil remains of them than we have in the doubtful *Cyperites*. The *Antholites* of the Coal measures, once believed to be a grass, is now known to be merely a fruit-bearing spike of some coniferous plant. During the "age of conifers" a large differentiation took place in this order. There were coniferous trees living during the Carboniferous period which bore adiantum-like leaves, similar to those still produced by the peculiar conifer from Japan known as *Salisburia*, and plum-like "stone fruit," resembling in some respects the fruit of the yew, which has long been familiar to geologists under the name of *Trigonocarpum*. These fruits are found in such abundance in some sandstone beds of the upper Coal measures as to make them appear almost composed of nothing else. Pines with the ordinary needle-shaped leaves, and cone-bearing, have always

been abundant. The fossil plant known as *Pothocites*, found in the Scottish Coal measures, is supposed by Mr. Carruthers to be the spike of some aroideous species; but is so imperfect that it is difficult to base any definite conclusions upon it, and some botanists deny its phanerogamous character altogether. Only eighteen species of fossil monocotyledonous flowering plants are recorded as having been discovered in the three formations, Trias, Lias, and Oolite, and some of these are doubtful. This proves how very scanty must have been the flower-bearing flora, for we get no similar poverty of fossil ferns or conifers. The Wealden formation was deposited as a delta at the mouth of a large river—a river watering an enormous area of country, which must have been more or less covered with plants; and the Purbeck beds were formed along the floor of an extensive fresh-water lake. No geological conditions could have been more favourable for the preservation of land plants than these, and yet the number of flowering species is extraordinarily few. Remains of insects, their wings, legs, heads, &c., are preserved, as we have seen, and there is no reason why we should not have found dicotyledonous flowering plants had they been abundant.

In a Greenland formation which Professor Heer calls *Lower* Cretaceous, plant beds are found which have yielded extraordinary results; 138 species of ferns, 75 of monocotyledonous flowering plants, and one dicotyledonous have been described. In the

greater part of Europe the Cretaceous period was marked by deep-sea conditions, so that we have little expectation of finding fossil land plants. The *Upper* Cretaceous formation in many places seems to have been favourably deposited for the preservation of these desirable plants. It should be stated, however, that in the opinion of certain geologists some of the so-called "Upper Cretaceous" beds, especially those of Dakota, are regarded as being possibly intermediate in age between the Cretaceous and Eocene, so that they form "passage-beds" between the Secondary and Tertiary epochs. The most remarkable strata of these deposits are perhaps those of Dakota in the Western States of America, whose fossil plants have been figured and described by Professor Lesquereux.

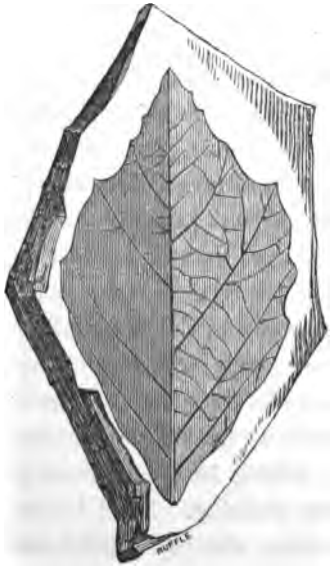
Fig. 1.



Leaf of *Quercus primordialis*, Upper Cretaceous Beds, Dakota.

Here we find no fewer than one hundred species of dicotyledonous plants. In the Aix-la-Chapelle beds a large number of fossil leaves, &c., have enabled botanists to chronicle the incoming of many orders of plants at an earlier date than had been before imagined. In tropical Africa, Greenland, and New Zealand, plant-bearing beds of so-called Upper Cretaceous age have also been explored, and the occurrence of the remains of monocotyledonous and dicotyledonous plants in them, proves that these groups were wide-spread and tolerably abundant.

Fig. 2.



Leaf of *Betula beatriciana*, Upper Cretaceous Beds, Dakota.

All the coniferous and most of the monocotyledonous plants are "wind"-fertilized; and it is probable that up to the beginning of the Tertiary epoch no such beautiful perianthed monocotyledons as the lilies, tulips, &c., had made their appearance—that, in short, all the monocotyledonous plants were up to that time "wind"-fertilized. It is curious to note that when the dicotyledons first make their appearance, it is also the

"wind-fertilized" group which comes first. Thus, in the Upper Cretaceous beds of Dakota, out of the one hundred species of dicotyledonous plants described, no fewer than sixty-one are *apetalous*, such as the oaks, maple, &c. Many of them were catkin bearers, as the poplars. Of the remainder, thirty-five species are those possessing *polypetalous* flowers; whilst only *one* species is *gamopetalous*—that is, has flowers with the petals united into one piece. The greater proportion of "wind-fertilized" over "insect-fertilized" plants is always greater the farther we go back in geological time, thus indicating that the "wind-fertilized" appeared first. If we could get specimens of the entire plants, and were not forced often to depend on leaves alone for the identification of genera, there can be little doubt we should find the earliest dicotyledonous plants to belong to much more generalized types than any now existing. Such is the opinion of Baron Ettinghausen, who has studied and compared the Cretaceous and Tertiary floras of the world.

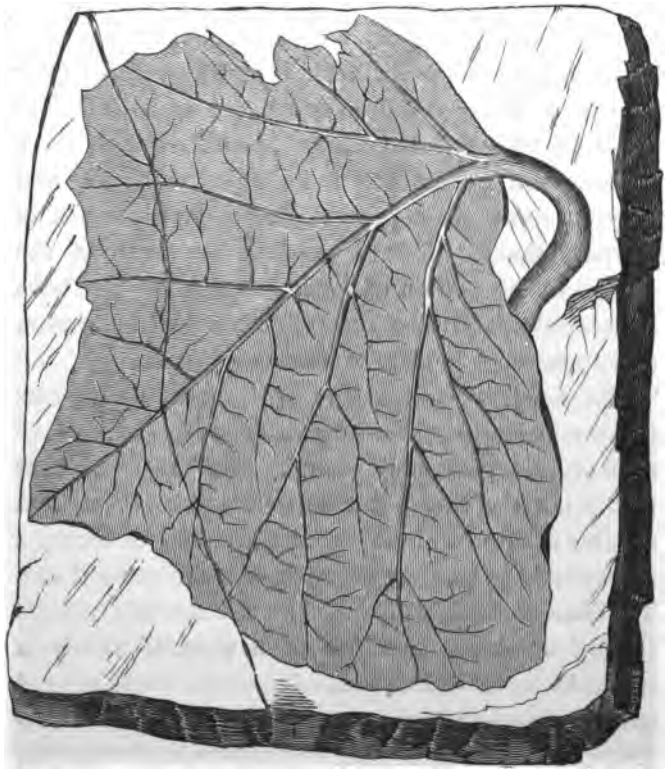
The order of floral occurrence therefore is, 1st, "wind fertilized" or *anemophilous* monocotyledons, such as grasses, sedges, rushes, &c.—gay-flowered or *perianthed* monocotyledons not appearing for certain until the Eocene period; 2nd, dicotyledons belonging to the "wind-fertilized" division, and bearing inconspicuous flowers or catkins; 3rd, dicotyledons with *true* flowers, but having the flowers composed of several pieces or

petals (*polypetalous*); and 4th, dicotyledons in which the petals are united, so that the flower or corolla is in one piece (*gamopetalous*). Of the *gamopetalæ*, the *irregular* flowers, such as those of the *Labiatæ*, *Scrophulariaceæ*, &c., were developed later still; whilst among monocotyledonous flowers like the Orchids, there can be no doubt their beautiful and irregular perianths, whose coloured parts are fused into one piece or "flower," have been specialized into these shapes from earlier and more primitive forms, and only assumed their present shapes in the latest of Tertiary times. This is certainly the order of the numerical proportion of fossil flowers, and we have little doubt it is also that of the actual succession and appearance in time of flowering plants.

The Tertiary epoch is that which up to a few years ago was believed to have first witnessed the introduction of dicotyledonous plants. We have seen that this is not the case. But, as we should expect from the line of argument employed, their number becomes numerically greater as we approach the present era. The Eocene beds of Hampshire and elsewhere have yielded abundant remains of a flora of nearly a tropical character, but which is on the whole related to that found in the older so-called "Upper Cretaceous" formations of Aix-la-Chapelle and America. The Eocene plants include many genera now deemed peculiarly Australian, such as the *Proteaceæ;* smilax,

dryandras, acacias, azaleas, cactuses, aroids, figs, &c., abounded; and their remains are found fossilized with those of fan-palms, feather-palms, and others.

Fig. 3.



Leaf of *Populus latior*, Upper Miocene, Œningen.

Climbing plants and llianes occasionally festooned the forest trees then, as they now do the woods of

the West Indies. It is in the Miocene period, however, that we have the remains of the most wonderful flora preserved, especially in the Molasse beds of Switzerland. From its warm temperate character, Professor Heer thinks the climate must have been about sixteen degrees higher in mean temperature than it is now. One peculiar feature about the Miocene flora is that it is an assemblage of existing genera which have since been rendered locally extinct, so that we now find them in parts of the world at immense distances from each other. This has been greatly the result of subsequent geographical changes, some of which, such as those occurring in the Glacial epoch, were of an extraordinarily rigorous character. No fewer than seven hundred species of fossil phanerogamous plants have been obtained from the Swiss Miocene beds alone. Of these nearly three hundred were trees, and two hundred and fifty were shrubs. One hundred and sixty species were herbaceous flowering plants; many of them grasses and sedges; others with showy blossoms or corollas. The Miocene flora plainly shows us that a great differentiation had taken place in the form and grouping of insect-fertilized plants since they first appeared. We now meet with *Composite* flowers, where we have an abortion of some and a specialization of other florets, all diminished in size and peculiarly arranged in disks, so as to suggest the popular idea that the whole colony is only one flower, as is certainly the notion with the

daisy, dandelion, and sunflower. Such a modification of floral parts would only be expected by a botanist

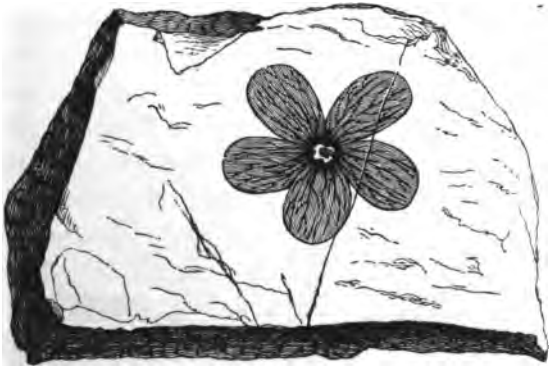
Fig. 4.

Leaf of *Acer trilobatum*, Upper Miocene, Œningen.

in periods subsequent to the first appearance of true flowers, and would be regarded as produced by a

gradual modification. *Papilionaceous* flowers, like those of the pea, remarkable for the different sizes and shapes of the petals and their different colours, seldom the same in any two genera, abound in the Miocene beds. There are traces of them in the Eocene, where a nearly allied group, the *Mimosas*, like unto them in the construction of their fruits (*legumes*), are not uncommon.

Fig. 5.

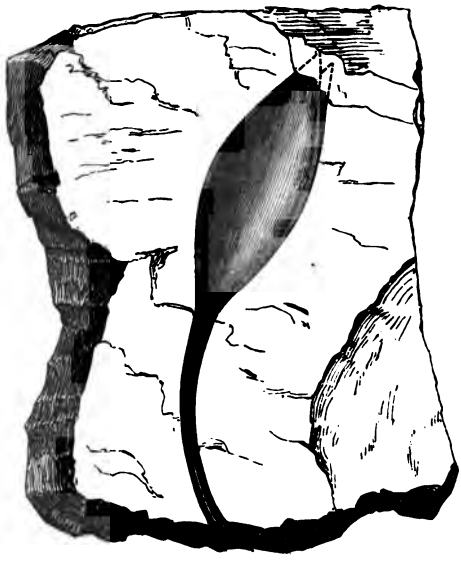


Fossil Flower (*Porana œningensis*), Upper Miocene Beds, Œningen.

Water lilies covered the quiet surfaces of Swiss and English lakes during the Miocene period as they do in our own day. Cinnamon trees (now characteristic of Japan) abounded, Proteaceous plants (at present peculiar to the southern hemisphere) grew by their side, magnolias and tulip trees (well-known American forms) sprang up in botanical fellowship. In company with them were almond trees, plum trees, haw-

thorns, and many others familiar to the warmer temperate regions.

Fig. 6.



Fossil Leguminous Fruit (*Podogonium knorri*), Upper Miocene Beds, Œningen.

The Pliocene and Glacial periods witnessed the local extinction of many of the plants whose more generalized character enabled them to grow together during Miocene times, and the geographical distribution of others to the areas they now occupy. In a great measure the entomophilous flora has been other-

wise specialized since then—many plants have become *monœcious* or *diœcious*, dimorphic and trimorphic, cleistogamous or otherwise aborted. These changes are still going on, and the appearance of man has done no little to add to the disturbing agents in the floral equilibrium of the world.

We have seen that the appearance in geological time of the most beautiful or sweetly perfumed flowers is also that of the insects which now habitually frequent flowers. And as the wind-fertilized precede the insect-fertilized flowers in order of geological time, we contend that the latter have been modified from the former. Not unfrequently the same genus of plants contains both insect- and wind-fertilized flowers, as in our own common ash (*Fraxinus excelsior*), which is apetalous, and the species naturally abundant in the south of Europe (*F. ornus*), and now in our ornamental shrubberies, which possesses a corolla, and is therefore probably insect-fertilized. We do not mean to assert that the plants which bear the most beautiful flowers are the most highly organized, any more than that such specially attractive insects as the *Lepidoptera* are the highest in point of organization and development. Some of the *Neuroptera* among insects, as the white ants (*Termites*), and many among the *Hymenoptera*, as bees and brown ants, are, as we have seen, more cerebrally developed. We have, therefore, a peculiar

aspect of evolution here presented, not necessarily towards *higher* organization (as some people think is imperative in evolution), but in the direction of special adaptation to each other's necessities and well-being, on the part of two groups of organisms having no other connection with each other than that of being mutually adapted to one another's requirements.

CHAPTER III.

THE GEOGRAPHICAL DISTRIBUTION OF FLOWERS.

THE conditions affecting the distribution of flowering plants over the surface of the earth are both numerous and various. And, as many of these conditions have arisen since flowering plants first appeared, it follows that the dispersion of the latter is more or less in proportion to the former. In addition to the physical conditions, which were changing all over the surface of the earth during the entire Tertiary epoch, there are others of an equally irregular nature which cannot fail to influence the distribution of the higher plants. The wind carries some seeds to great distances, oceanic currents convey others to lands far asunder; aquatic birds unconsciously disseminate seeds which adhere to their plumage and feet, and wild animals carry them in their fur. We are not here taking into account the disturbing interference of mankind in altering the equilibrium of the floral world. The tendency of the flora of a country is to be adapted to the climate and its physical and biological conditions. Hence, if such country remain unaltered for long periods of time, its flora will assume distinguishing characters. This is the case,

for instance, with the numerous tributaries of the river Amazon, each of which has a distinctive flora of its own.

To account for all the reasons why certain great families of plants occupy the regions in which we now find them flourishing, is beset with no small difficulty. Not long ago the knot was cut, rather than untied, by naturalists believing in "centres of creation;" which meant that the great families of plants were created at or near the spots where we now find them. Even this doctrine would have been sorely tried had it been forced to account for the many anomalies of plant distribution which recent botanical research has multiplied. Difficult although the task be, we are not without a glimmer of some of the possible causes which have been in operation.

Climate appears to be one of the chief influencing causes of plant distribution, and as this greatly depends on physical geographical changes it follows that the latter thus indirectly as well as directly modify it. The degree of heat or cold also causes groups of flowering plants to be gathered together where the conditions are favourable. In this way we have the various floras generally spoken of as "Arctic," "temperate," and "tropical." A large number of plants may be called "soda-loving," and these usually abound near sea-coasts. But as we also find them growing over areas underlaid by granite partly composed of soda-felspar, as well as

inland where brine-springs or salt-works abound, we perceive that the chief cause of their being *maritime* is not that there is any mysterious influence exercised over them by the sea, but because such a situation affords them the necessary amount of soda they love.* These "maritime" flowering plants are usually distinguished by the possession of thick and succulent leaves, and these characters may be due in some measure to the absorption of moisture by the salt in the tissues. Heat and cold, however, seem to be the chief influencing causes of distribution. Some families are entirely confined to zones on each side of the Equator, where the temperature has a mean annual amount suitable to them. Others are representative, and take the places of the former where similar conditions prevail. As we proceed from the Equator towards the North Pole we find vegetable life in more or less parallel zones, each with its distinctive groups. This general but manifest arrangement is that first to strike our attention, and it was therefore known long before geological or biological causes were taken into consideration in the distribution of flowering plants. The zones were termed respectively the equatorial,

* We have frequent illustrations of the influence of soils in the distribution of plants. Many affect the calcareous habitats, and grow most abundantly on limestone and chalk, whilst other plants, as the foxglove, appear to eschew such conditions. The pretty Cornish heath (*Erica vagans*) is almost restricted to the serpentine rocks; and the rare *Erytricum nanum* grows only on granite mountains. The memory of the reader will supply numerous other instances of the specializations which have confined the distribution of certain plants to certain soils.

tropical, sub-tropical, warm-temperate, cold-temperate, sub-Arctic, Arctic, and Polar. In the southern hemisphere there is of course a corresponding arrangement, but as the largest masses of land are grouped in the northern, the distribution of terrestrial plants into zones is there more perceptible. It was next seen that a vertical parallel to the geographical distribution of plants into the above-mentioned zones was found when we ascend high mountains at the Equator. We then pass from tropical conditions of climature through every intervening stage up to Arctic, which may be found permanently above the snow line. And, although the same *species* of plants are not always found at the height above the sea where the temperature corresponds to a certain latitude north, there is such a marvellous resemblance that they are called "representative" species. In not a few instances, however, the species are identical, although varietally different; so that they are geographically isolated from their natural homes, and are so many floral colonies which have migrated from their original centres.

This lateral and vertical grouping of flowering plants affords us a rough and ready classification. It has also a bearing upon the distribution of any new incoming species, for it affords an enormous series of physical conditions where growth may occur. The vertical decrease of temperature upwards has allowed many Arctic plants to be dispersed along the tops or

1. HAZEL. *Corylus avellana.* 2. NETTLE. *Urtica dioica.*
3. WHITE POPLAR. *Populus alba.* 4. ALDER *Alnus glutinosa.*

sides of extensive mountain chains, so that they are now found at great distances from their metropolis or proper home.

Still, after we have allowed the utmost for the arrangement of vegetation into zones of latitude and zones of altitude, we have scarcely done more than roughly formulate the facts. For, although the climature may be similar, and the soils on which they grow alike in their mineral constituents, how different are the floras, say of Central America, from those of similar latitudes in the Old World! Each has its heat- and cold-loving plants grouped at the foot of, or far up, its mountains; but frequently they have little else in common. It is not that plants from one region will not grow in another, for horticulture is every day disproving such an idea. Cactuses grow as well in South Europe and North Africa as in Mexico; forests of quinine trees have been planted along the slopes of the Himalayas, where they are now flourishing as vigorously as in their natural Peruvian habitats. The cotton and tobacco plants have been cultivated wherever the climate is suitable, latitude or longitude notwithstanding. Fruit-trees, cereals, and useful vegetables have accompanied the migratory progress of civilization. In Europe and North America we are every day proving the possibility of many plants growing in gardens which are not indigenous. From the slopes of Andean and Himalayan mountains, flowering plants have been obtained for the sake of their

pleasing blossoms, which grow in our gardens side by side with others from the plains of Siberia, the "bush" of the Cape of Good Hope, the Llanos of Brazil, or the "scrub" of Australia. Instances, however, are needless to prove that plants can grow in other places than those to which they are indigenous; and we only call attention to the fact to show there is not the slightest proof for the statement that plants are always found in the very best situations which could possibly be assigned them. The *Anacharis* grows much more luxuriously in sluggish English rivers and canals than it does in its natural Canadian waters: the watercress increases to a size in New Zealand streams it never attains in Europe! The mere separation of areas of land by oceans makes no difference in the existing relations of floras. Thus, although Japan is part of the Old World, its flora is in some respects more nearly connected with that of the Southern States of North America than with the Asian, although it is actually part of the great Asiatic continent! There are more than three hundred species of plants common to the Southern States of America and Japan than to Europe. Again, we have in some countries *floral outliers*—that is, remnants of floras which are known to us elsewhere only in the fossil state. This is the case in some parts of Australia and Madagascar; as well as in such islands as the Seychelles, Mauritius, and Bourbon Island, which may be regarded as fragments of a submerged continent

whose peculiar flora has lingered to our day on these unsubmerged parts. Not unfrequently we find solitary groups of plants where they have no right to be, as for instance *Raymondia* and *Dioscorea* growing on the Pyrenees, Swiss alpine grasses at the Straits of Magellan, and our common English quaking grass (*Briza media*) at the Cape of Good Hope. Lapland plants grow on the Swiss Alps, and even on the Pyrenees; on English, Irish, Scotch, and Welsh mountains. These anomalies are quite as peculiar as if we found a Chinese settlement on the Pyrenees, a genuine Swiss family Robinson living at the extreme end of South America, or short-statured Lapps leading their peculiar lives and building their strange-looking huts in spots now frequented by the annual tourist! Besides these anomalies in the distribution of flowering plants, we have others, quite as striking, in the manner with which *conspicuous* or gaudily-coloured and *inconspicuous* or unattractive flowers are distributed over oceanic areas where there appears no reason, in climatal and other surroundings, for the contrast.

It soon becomes evident that in the geographical distribution of plants we have had (1st) geological and physiographical laws at work, and (2nd) biological influences in long-continued operation. We find that some such law as the following is capable of being roughly applied to the subject of plant distribution:— The *lowest* organized families are the widest dissemi-

nated; the lowest forms are those which, palæontologically speaking, are the oldest; and we should therefore expect to find them occupying all the available areas of growth the whole world over. Thus, of the lichens brought by Sir James Ross from high latitudes in the southern hemisphere, nearly all were found specifically identical with those growing in the northern. The distribution of mosses and ferns appears to be limited only by climatal conditions, or rather by the physical changes which have brought about the latter. Coniferous trees, although characteristic of conditions ranging from temperate up to Arctic, have a cosmopolitan occurrence. Grasses, again, are of almost world-wide distribution. Of dicotyledonous plants the genera with insignificant flowers are found over wider areas than those possessing showy corollas. Now this is the degree in which we should expect to find plants distributed, seeing that it is the order of their geological appearance and evolution. With an order of plants it by no means follows that because it is older, geologically speaking, than another, it will therefore be found over a more extensive area; for the later formed order may possess structural and other advantages which have enabled it to outstrip its predecessor. But where we have to deal with the distribution of large groups of plants, like the various acrogens, monocotyledons, coniferæ, and apetalous and petalous dicotyledons, it is seldom we find one group stamping out another. The *Cycadaceæ* appear to

have been worsted in the battle for life. Once they had a geographical distribution that was perhaps co-extensive with terrestrial conditions, for we find them abundantly represented by fifty-eight fossil species in the Oolitic formation. Now they are confined to districts which we may regard as outliers of their former universal distribution—districts separated from each other as far apart as possible, such as the West Indies, South Africa, Ceylon, India, Japan, the Malayan Archipelago, and Australia Many genera of living plants once had a much more extensive geographical distribution than they now possess. This is notably the case with the *Sequoias* (better known as *Wellingtonias*), of which there are now only two species, both attaining a gigantic size. One of these is the well-known *Wellingtonia*, which occurs in isolated spots in California and various parts of the Sierra Nevada. The other species (*sempervirens*) has a range extending from California to Nutka Sound. But during the Chalk period *Sequoias* were European and even African plants; and they continued to have a very extensive European distribution even in the Miocene epoch. The same with the *Magnolias*, which are among the first true flowering plants to appear in the geological record. We find them in European Cretaceous beds; they were abundant and cosmopolitan during the Miocene period, but they are now to be found only in China, Japan, India, and the Southern States of North America. The *Banksias*, so abundant in

England and Europe generally during nearly the entire Tertiary epoch, are now almost entirely confined to Australia and Tasmania. The *Dryandra*, a nearly allied, and, geologically speaking, a more ancient genus than the *Banksia*, was formerly very abundant in the northern hemisphere, both in the Old and New Worlds. Now it has even a more limited geographical range than its relative, for its distribution is limited to the south and south-western parts of Australia. The narrowing of the distribution of these remarkable plants to the limited areas where they are now found, is undoubtedly due chiefly to the intensity of the physical geographical changes which occurred during the Glacial epoch; for we find them tolerably well represented in European deposits up to the setting in of the extended cold of the Great Ice Age.

The physical changes which have taken place during each succeeding geological period, have added to the diversity of the physical surroundings of plants. The sum total of these conditions has been constantly increasing, and with it the necessity for a series of corresponding changes on the part of plants to adapt them to the environments. Whether we admit the older doctrine of the necessity for the special creation of new species adapted to flourish under the conditions brought about by some recent geological change, or accept the more philosophical conclusion that varietal changes on the part of plants have on the whole kept pace with the change in external

physical conditions, the result must be the same, viz. an increase in the number and variety of flowering plants from the time of their first appearance up to our own era.

Most species of flowering plants have an elastic vitality which enables them to adapt themselves to various changes in their environment, such as difference in climate, soil, and moisture. The range of this elasticity varies considerably. Some species seem to possess very little, and the slightest alteration of the physical conditions around them influences them for evil. Others are affected little except by very sudden transitions from one kind of surrounding to another. The longer plants have lived under the same unvaried external physical conditions, the more unable they are to adapt themselves to sudden changes. Witness the tendency of introduced Australian plants to bloom in our northern winter. If we compare the time of flowering of the same species of plants in places where the mean climature is different, we plainly see this power of adaptability on their part. Thus our common British wild flowers bloom at different parts of the summer, from May to the end of August, according as we observe them in the south of England and pass on to the north of Scotland. The elm will open its leaves in Naples early in February, in Paris not till late in March, and with us about the middle of April. We all know how much sooner cherries, plums, apples, pears, &c., ripen in the south of Europe than in

England. Sometimes the climates of countries are such that places farther north will grow plants better than others more to the south. This, owing to the warmth diffused by the Gulf-stream, so alters the climate of Sweden that the liliac and elm show their leaves sooner at Upsala than in Paris; such evergreen shrubs as the Portugal laurel and laurustinus grow better in the north of Scotland than at Lyons, owing to the extremely severe cold which characterizes the continental winter of the latter, whilst that of the former is more equable.

A change in the *fauna* of a country may affect the distribution of the *flora* to a very considerable degree, in altering the balance among native species of plants by giving some forms an undue advantage over others. Thus, it is found to be an exceedingly difficult thing to grow European fruit-trees in Central America on account of the ravages of the numerous leaf-cutting ants, which eat up and destroy the young seedlings or shoots directly they appear. Native shrubs and trees are mostly armed against these insects, or possess some peculiarities by which they are able to propagate themselves in spite of them. Herbivorous animals are fonder of certain plants than others, and if introduced will eat down some species, and thus give others such an opportunity for development that they overrun the ground. In this way, owing to the introduction of hogs and goats into the island of St. Helena, the latter have destroyed the native flora. Or it may be

that, owing to the extreme differentiation in the floral organs, some species can never hope for an extensive geographical distribution, simply because they have come to be entirely dependent on the presence of certain insects for their fertilization. The *Yucca* has been introduced both into this country and the northern parts of the United States, and it grows luxuriantly and flowers abundantly, but it never produces seed, simply because it is absolutely dependent on the presence of a little moth called *Pronuba Yuccasella.* Thus certain plants are messmated with certain insects; and seeds cannot be produced unless both are distributed together. This is notably the case with the orchids, both English and exotic; many species, like the liliaceous *Yucca*, have at length been narrowed to the cross-fertilization produced by the visits of selected species of insects. Darwin has shown that birds are active agents in the dissemination of aquatic plants, by carrying their seeds attached to their plumage or feet. Some plants have seed or seed-vessels provided with hooks, so that they are torn off by passing animals, and are thus carried to great distances in their hair or fur. Many species of Cape plants are notable for this habit. The raw wool imported into this country for manufacturing purposes from Australia, Brazil, and the Cape, is often full of the seeds of native plants, which have got entangled after this fashion. In countries where the climate is favourable, some species may have been distributed

by means of oceanic currents, after the manner with which certain West Indian seeds are cast on the Devonshire and Cornish coast by the Gulf-stream. Even icebergs have been seen with bright-coloured flowers blooming on the patches of soil they may have been carrying; so that Arctic as well as tropical species may have been thus disseminated whenever opportunities were favourable.

The wide-spread distribution and numerical abundance of composite flowers, such as the thistle, daisy, chrysanthemum, &c., is due chiefly to the special means of dispersal which this cosmopolitan order possesses. In many species the dried parts of the calyx form the well-known feathery *pappus*, as seen in the "clock" of the dandelion. This is attached to the upper parts of the seeds, and is large enough to act as a parachute and carry them away to great distances from the parent plants. This order assumes arborescent characters in many oceanic islands remote from each other, such as the Galapagos Archipelago, Juan Fernandez, New Zealand, St. Helena, and the Sandwich Islands. Mr. Wallace thinks that this special assumption of arborescence on the part of many species of *Compositæ* thus distributed is an advantage to them, by combining increased longevity with the advantage of increased size in the struggle for life with ferns and other plants which are apt to colonize islands. Their advantage in longevity would enable them to be certainly crossed

at intervals of time, notwithstanding the scarcity of insects; whereas annuals might bloom repeatedly without being crossed.

Wallace speaks of the floras of oceanic islands as possessing *fragmentary* characters. Their flora is evidently made up for the most part of waifs and strays, brought from distances by prevailing winds and currents, or by sea-birds. This appears to be true of most of the scattered islands of the Pacific, although it is not so of islands nearer continents. Ferns are notably more abundant in islands than on continental areas, and this may be due to the lightness of their spores and the ease with which the wind can carry them over great distances of sea, as well as to the humidity of the climates of islands, which favours their instant development. Their abundance on islands may also be partly ascribed to the general absence of other plants, which cannot grow there because insects are not present; and so the ferns have fewer competitors and antagonists to struggle with. Many of our leading botanists are of opinion that the reason why entire orders are absent in the oceanic islands of the southern hemisphere is that the insects which elsewhere habitually frequent their flowers are absent also. So that, as in the case of the *Yucca*, if gay-flowered species were to be transferred by some means to these habitats, they would not seed, or would only partly seed, and thus would not be fit competitors to rivals better adapted to the conditions of

life. Their only eventual chances of success in the struggle would be by losing some old characters, and assuming others more serviceable to them. Species of plants may be found in islands actually undergoing these changes. Thus, at Tristran d'Acunha, introduced *Pelargoniums* may be seen blooming, although there are no insects present to be attracted by the bright colours of their corollas. On Kerguelen's Land there was found, during the "Erebus and Terror" expedition, considerable quantities of a species of *Cruciferæ*, called *Pringlea*. This is perhaps the only member of its group which is not habitually crossed and fertilized by insects. The *Pringlea* of Kerguelen's Land, however, is *wind*-fertilized. Its petals have been aborted, the stamens enlarged, and all the organs of fructification modified accordingly. The winds are violent in Kerguelen's Land, and insects scarce. Even what few species of the latter are present are often modified. It is no uncommon thing to find species which are winged elsewhere, in oceanic islands *wingless*. This is particularly the case with the beetles, whose heavy bodies, if winged, would often be carried out by the wind to sea when the insects were flying, and thus they would be destroyed. The little use islandic insects make of their wings, therefore, causes them to be gradually aborted; and thus they become in time absolutely unable to fly, the very elytræ being soldered together! This wingless condition, however, is an advantage to the

insects, for it ensures their not being blown out to sea and drowned during attempted flight. The *Pringlea* is a plant in an analogous position. Unless it had been modified in all its floral parts, so as to adapt it to wind- instead of to insect-fertilization, it would long ago have been extinct. Few botanists will deny that such a modification has actually taken place in this species.

The "fragmentary" character of the floras of oceanic islands, as compared with the more stable and broader-featured floras of continents, is apparent in many ways. Mr. Wallace shows that many important orders of plants are wholly absent in some of the larger of the South Sea Islands. In Tahiti, for instance, no fewer than "sixty-six orders are unexpectedly absent." In the Sandwich Islands, on the contrary, we are surprised by the abundance of labiate plants—undoubtedly one of the most specialized of orders. We find an inequality in the distribution of plants in the South Pacific on its easterly and westerly sides. A closer investigation shows that this inequality is related to the distribution of butterflies, moths, and hymenoptera. Where they are absent, or scarce, as on the eastern islands, there are fewer bright-flowered species; where they are present, as on the western side, about the Fiji Islands, for instance, there is a great variety of showy flowered species. Nowhere is the collateral distribution of insect-loving flowers and of flower-loving

insects more plainly visible than in the eastern and western islands of the South Pacific.

Sometimes we are presented with startling exceptions to this rule, as in the island of Juan Fernandez; here, in conjunction with entomological poverty, there is both floral variety and abundance. One species of butterfly, very rare in its occurrence, and four species of moths evidently derived from the adjacent coasts of Chili, are all the flower-haunting insects which have been met with. Among the showy flowered plants abundant here are the Winter's bark, bright-blue flowered *Bignonias*, white myrtles and lilies, and brilliant yellow composite flowers. This general absence of insects and abundance of showy and even large-flowered plants, is explained by the fact that at least two species of humming birds, most abundant in individuals, take the place of insects, and habitually frequent the flowers. Mr. Moseley, naturalist to the 'Challenger' expedition, speaks of having seen these birds with masses of yellow pollen clogging the base of their beaks. Mr. Wallace quotes Tahiti and Juan Fernandez, both surrounded with the same kind of climatal conditions. In one there is a marked absence of flowers—in the other an abundance. This is accounted for only by the general *absence* of both insects and flower-frequenting birds in Tahiti. Sometimes, as in the Galapagos Islands, plants which elsewhere are showily coloured, bear inconspicuous flowers. Here we have an illustration

of the changes in the reproductive organs similar to those which have been developed to so extreme a degree in the *Pringlea* of Kerguelen's Land. All the flowering plants in the Galapagos Islands are remarkable for their inconspicuous inflorescence. When we couple with this fact the total absence of both insects and humming birds, we at once perceive the reason. On the other hand, in the Sandwich Islands we have some remarkable showy flowers, borne in immense numbers, as the *Metrosideros*—a genus peculiar to the South Pacific Islands. These are habitually visited by honey-sucking humming birds. In every case where birds replace insects in visiting flowers for the sake of their honey, they cross them in some way or another. In the genus *Marcgravia*, abundant in Nicaragua, Mr. Belt has shown there is a special arrangement for dusting the backs of humming birds with pollen whilst they are poised and sucking the honey. The most remarkable flora of these oceanic islands, however, is undoubtedly that of New Zealand. The islands of New Zealand must have been such for a long period of time, geologically speaking; although there can be little doubt of its former land connection with Australia. Even some of the migratory birds have still an eastern and western migration, just as some of ours have a northern and southern. The flora is remarkable for its *inconspicuous* flowers, and here again, as in the Galapagos Islands, we have associated with it the scarcity of lepidop-

terous and hymenopterous insects. Dr. Hooker states that this flora is as strikingly deficient in sweet odours as it is in showy flowers.

The combination on a small scale, by which the different species of *Compositæ* ensure the visits of insects, through massing their florets together on one head or receptacle, appears to be imitated on a large scale by certain plants, such as those which blossom where the climature is Arctic in its character. No matter whether this Arctic climature occur in Spitzbergen or on the margins of the Alpine and Pyrenean snow-lines, the effect is the same. It has been used as an argument against the generalization that the colours of flowers are intended mainly to attract insects, that we have large areas in the Arctic regions clothed with the most beautiful and showy flowers during the short but hot summer which intervenes. And it has been somewhat hastily stated that no insects were to be met with, and therefore the colours of the flowers could have no reference to them. We might reply that they certainly could have no reference to the appreciatory tastes of man either, for the Arctic regions are those he shuns rather than otherwise. H. Müller has shown, however, that the carpets of bright floral masses to be seen on or near the snow-fields of the Alps, have their individuals thus packed closely together, so as to produce the largest mass of attractive colour. We have seen that the same principle is adopted on an infinitely smaller scale by

every composite flower. The result of these patches of colour produced by Alpine flowers (and singularly enough all the individuals of one species seem to be growing together) is that the numerous butterflies are attracted to their neighbourhood, and stay there sucking the honey from the flowers. The latter have mostly long throats, either produced by gamopetalous corollas, as in the *Gentians*, or by a gamosepalous calyx and long-spurred petals, as in the various species of *Caryophyllaceæ*. The neighbourhood of the snow is too cold for bees, which are never seen on these Alpine flower-beds; and even if they were, the butterflies would have an advantage over them, for their long probosces would better enable them to get at the bases of the deep-throated Alpine flowers. We do not doubt that when the flora of the Arctic regions has been examined by as careful observers as H. Müller, it will be found exposing its bright masses for the similar purpose of attracting lepidoptera. One special adaptation is to be observed of this Arctic flora—the majority of species are *perennial* in their growth. *Annuals* would have little chance of dispersing their seeds, or of surviving the long and dreary winters of these icy latitudes. The annuals, therefore, have gradually given place to perennials, the latter being better adapted to withstand the extreme rigours to which all the flowering plants must be exposed in these high latitudes. Nor should the peculiar *trailing* or procumbent character of

certain plants which elsewhere are arboreal or arborescent, be omitted. Of such are the procumbent beeches, willows, and even a coniferous tree which never rises more than five inches above the ground. This procumbent habit causes them to be covered up with snow during winter, so that they are thus effectively protected against the extreme cold of the atmosphere.

CHAPTER IV.

THE GEOGRAPHICAL DISTRIBUTION OF FLOWERS—*(continued)*.

THE distribution of flowering plants considered in the previous chapter has been brought about more by biological and climatal causes than through geological operations. We now proceed to note how the latter may have largely influenced plant distribution. The *Raymondia* and *Dioscorea* of the Pyrenees may be regarded as survivors of the Miocene flora, just as we believe the solitary species of European palm (*Chamærops humilis*) to be a dwarfed relic of the gorgeous palm flora which abounded in Great Britain during the Eocene and partly during the Miocene periods. The light which has been thrown upon some of the anomalies of plant distribution by the wonderfully lucid theories of Dr. Croll, as set forth in his 'Climate and Time,' has been gratefully accepted by most philosophical botanists. Dr. Croll has shown the changes which occur in the eccentricity of the earth's orbit: when that eccentricity is greatest, it produces a great alteration in the climature of the northern and southern hemispheres alternately. One enjoys a long period of great warmth; the other suffers from

an equally protracted rigorous cold. All the vapour carried by the winds over the cold hemisphere falls as snow, and this increases down to very low latitudes, swathing islands and continents in ice-sheets, as Greenland is, and as we know Great Britain was during the Glacial epoch. Such warm oceanic currents as the Gulf-stream are then deflected, and all their heat is thrown into the oceans of the opposite hemisphere, to raise its temperature still higher. The extreme cold of the ice-clad hemisphere causes the trade-winds to sweep for some distance over the Equator, cooling the latter area, so as to make the zone of greatest heat tropical instead of equatorial. Such, says Dr. Croll, must be the effect of a set of physical changes which result from the position in which one of the two hemispheres must be in when the earth's orbit is experiencing its highest degree of eccentricity. A "Glacial" period would be going on in one, and a sub-tropical or "Eocene" epoch in the other.

Mr. Darwin has accepted the above slightly-sketched theory as explanatory of numerous anomalies in the distribution of some species of flowering plants. If it be true, then each hemisphere has been alternately enjoying or suffering a warm and a glacial climate during all geological time. There is no question as to a glacial period in the northern hemisphere, and recent explorations show that New Zealand and some parts of Australia contain traces of former glacial action. Under the Equator, in such mountainous regions as

the Cordilleras of the Andes, there are moraines and other signs of intense glacial action at a much lower level than these phenomena could now be produced. Mr. Croll shows that the natural result of such a cooling of equatorial regions as would follow from the cold trade and other winds blowing so far across the Equator into the southern hemisphere, would cause the hottest part to be near the southern tropic, and there cause glaciers to descend to a much lower level at the Equator than they could form at the present time.

It is evident that such a physical condition of things would be highly favourable to the migration of plants from one hemisphere to another. This would be especially so with regard to the passage of Arctic and sub-Arctic species, owing to the greater preponderance of land in the northern hemisphere. If glaciers could come down to comparatively low levels in Central America, then some members of an American Arctic flora could easily cross the Equator along the edge of the snow-line, and thus gradually pass to the extremest end of the South American continent. In Arctic regions we have land spreading into the Old World as well as into the New, and the dispersal of an Arctic flora could take place in both to as low latitudes as geographical circumstances would permit. Hence, we can understand how, as Dr. Hooker has shown, there are between forty and fifty species of flowering plants found growing at Terra del Fuego, which are common to North America and Europe.

Darwin mentions that on the mountains of Equatorial America there is a host of peculiar species of plants belonging to European genera; and on the Organ Mountains of Brazil both Arctic and Antarctic plants are found commingled in strange brotherhood, eloquently testifying to the alternate glaciation and heating of the northern and southern hemispheres, which have at length thus brought them unexpectedly into company.

Mountain ranges have afforded capital means for Arctic, sub-Arctic, and temperate plants to extend their range during our northern glacial epoch, even into and beyond equatorial regions. Darwin states that in Africa several forms characteristic of Europe are to be found on the Abyssinian Mountains, in company with plants which have come southerly from the Cape of Good Hope. European plants are also found on the mountains near the Cape; whilst even on the Cameroon Mountains, in the Gulf of Guinea, Dr. Hooker has shown there are species very nearly related to European forms, and which are doubtless descended from the same parent stock. Even the mountains of the Cape Verde Islands have European temperate plants indigenous to them. The same is true of the Himalayas, where, in addition to European species, there is a large number of "representative" plants. Far away into the southern tropic our northern plants have found their way, their greater number, due to the larger area of land where they were raised,

having enabled them to invade the southern hemisphere. "A list of the genera of plants collected on the loftier peaks of Java," says Darwin, "raises a picture of a collection made on a hillock in Europe!" On these tropical mountain peaks and flanks, plants from extreme northern and southern latitudes may be found growing together, having been shaken up into this peculiar geographical heterogeneity by the alternate glaciations of the northern and southern hemispheres.

The gradual extension during our Glacial period of the Arctic flora into temperate regions, of the temperate into tropical, of the tropical into equatorial, and of the latter actually into the southern tropic—each great zone giving temporary place to the other—must have effectively operated in contracting the once extensive geographical distribution of plants in the northern hemisphere, when there had accumulated no ice, as during the Miocene period. Thus many of the *Proteaceæ* must have then been effectively driven out of Europe, never more to return; for when the severe climatal conditions passed away, a newer and a more vigorous flora from Asia Minor replaced that of early Tertiary times. As the ice-sheet extended over greater areas, and the glaciers came down to lower levels, only Arctic plants could endure the climate, or such as could be adapted to the increasing extremes of cold. Doubtless many plants then assumed those peculiar characters we call

"Arctic," and have been distinguished by them ever since; just as some of the animals which lived before the Glacial epoch began were specialized to endure the extreme cold. This was certainly the case with the woolly-haired mammoth and rhinoceros, which were abundant in northern latitudes during this remarkable period. The cold of the Glacial epoch therefore must have been selective in no ordinary degree. All of the temperate plants which had lived on to the end of the Pliocene period were locally extinguished, or driven before the slowly advancing and increasing cold to other than their ancient localities; whilst only such remained behind as could be acclimatized to the Arctic, sub-Arctic, and cold-temperate conditions that prevailed, according to latitude. Thus it was that the *Proteaceæ* became Australian, the *Magnolias* and Tulip-trees chiefly North American. In a similar way with animals —the elephants and rhinoceri of Africa may be part of the stock driven southerly during Glacial times, of which our only modified survivors were the woolly-haired species already mentioned. The latter became extinct within pre-historic times.

The distribution of Arctic and sub-Arctic plants over areas far removed from the metropolis of that flora the Arctic regions, is remarkable for the incidental light it casts on the climature of the *last* geological epoch. Many circumstances connected with the Drift beds have led geologists to hold that

they were formed under conditions of extreme cold, such as are implied in the term "Glacial." They know that the mountainous regions of Scotland and the English lake districts have been swathed in land-ice, and that glaciers innumerable then filled most of the valleys of northern England. There is physical evidence enough and to spare that all these things really occurred. And the distribution of Arctic flowering plants over our high mountain peaks and hill tops, where the temperature is constantly chilled below that of the plains, can only be accounted for by the theory that this flora came into Britain when the Arctic climature of the Glacial epoch was prevailing here. This Arctic flora of the mountain tops has no relationship with that which carpets the meads in the vales beneath. The Circassian race of men is not more distinct from the Mongolian, than is the scattered, impoverished, and scanty Arctic flora of Britain from the lush and luxuriant temperate flora which has besieged and taken possession of the warmer and more fertile lowlands. Our highest British mountain, Ben Nevis, has its peak just below the line of perpetual snow; were it to be uplifted a few hundred feet it would penetrate the zone. On the Alps and Pyrenees, especially the former, we have physical conditions which exactly parallel those within the Arctic Circle. There we have a flora characteristically Arctic, found only along the snow-line, or in the immediate neighbourhood of glaciers.

The brightness and mass of colour which this "Alpine" flora puts forth every summer, are well known to tourists. No geologist doubts that the Arctic plants which partly constitute it originally spread from northern centres to latitudes as low as the Pyrenees. When the extreme cold of the last Glacial epoch which our northern hemisphere experienced began to disappear, and the ground was stripped of its ancient ice-sheet, plants were distributed by various organic and inorganic agencies such as we have mentioned, and so took possession. As the cold became less extreme and the mean climature warmer, so as to suit a flora like that which now carpets our fields and meadows and adorns our hedgerows, opposed alike to extreme cold and intense heat, that flora would be more favoured in its extension than any other. Our native flora is in a great measure a migratory extension from that of Asia Minor. As the warmer climature which succeeded the cold of the Glacial period extended, the incoming Asiatic plants took possession of all the habitats suited to them, leaving to their Arctic predecessors only the tops of the mountains and hills, too cold for themselves to flourish thereon, but wonderfully suitable to a flora specially adapted to a rigorous climate. Hence it is that this originally "Arctic" flora has become "Alpine," and is to be met with on nearly all the mountain peaks of Europe; whilst, as we have seen, some straggling members of it have

actually crossed the Equator, and are to be found wherever Arctic climature prevails, as on the margin of mountain snow-lines.

Of course this well-marked Arctic flora is often invaded by others of the temperate type which are hardiest, so that some of the latter have become "sub-Alpine." Still, it is remarkable how distinctive is this Arctic flora, as the following facts relative to its distribution will show: On the Engadine, a high valley in the Canton des Grisons, there are found eighty species of flowering plants unknown to the rest of Switzerland, although they are very common in the extreme north of Europe. On the Faulhorn, in the Berne Canton, there grow, at nine thousand feet above the sea-level, one hundred and thirty-two species, of which fifty-two are common to Lapland, and eleven to Spitzbergen. If we take the Alpine flora of Switzerland as a whole, we find that out of a total of three hundred and sixty species of flowering plants, one hundred and fifty-eight (or nearly one-half) are common to Scandinavia. These relations of the Alpine floras to the truly Arctic flora are verified by reversing the comparison. Thus, out of six hundred and eighty-five species of flowering plants found in Lapland, one hundred and eight are met with in greater or less numbers in various places on the Swiss Alps. In the Pyrenees we have nothing like such conditions of extreme climature as seem favourable to the development of this peculiar flora, but even

there we find that Arctic plants have become Alpine. No fewer than sixty-eight species have been met with on the Pyrenees which are common to Scandinavia.

Let us next turn to the distribution of flowering plants in islands, and the relation which such insular floras bear to those of the mainlands. We have already referred to what Wallace aptly calls the "fragmentary" character of the flora covering many of the islands in the Pacific. But this is true chiefly of those numerous clusters of islands which are as far removed from continents as existing seas will allow. Nobody doubts that perhaps many geological periods have intervened since they were part of a continuous dry land. Some of them are merely elevated coral banks; others the narrow peaks of submerged mountains. The enormous depth of sea-water intervening between these groups of islands tells the physical geologist plainly that this Pacific sea bottom has probably been submerging or sinking since the middle of the Secondary period. No wonder the flora capping the islands should be characterless; for when the original continent of which these islands are the highest summits began to be submerged, the flora of the globe had possibly not been evolved to a higher status than conifers and palms. The existing flora outside these has been made up—"taken in in numbers"—during succeeding geological periods, and gradually modified into the characterless conditions which distinguish these distant oceanic islands. We have seen

that climate and moisture, and the ease with which light spores can travel, have caused them to be specially the "paradises of ferns."

But it is possible to trace a relationship between the floras of some islands and those of continents, and in some degree to express the proportion which we may expect this relationship to hold. For example, we may lay it down as a good general rule, applicable to faunas and floras alike, that islands which are separated from adjoining continents by *shallow* seas have been insulated more recently than those islands which are separated by *deep* seas. We argue that, all other things being equal, the depth of intervening sea bears proportion to the time occupied in submerging the area, and cutting the island off from the continent of which it was formerly a part. If we compare the islands of Great Britain with those of the Azores, Madagascar, or the Mauritius, we see the applicability of this rule. Islands are in some degree zoological and botanical satellites to the adjacent continents; and the depth of sea is often equivalent to distance in latitude, in the degree of differentiation between the floral and faunal resemblances. Thus England is separated from the Continent only by the "streak of silver sea" we call the German Ocean, nowhere so deep as Loch Lomond; and we accordingly see that her flora is exactly that of the rest of Europe, with the exception of a rare species of orchid (*Spiranthes gemmipara*). On the other hand, we have

the Azores, Madeira, and the Canary Islands, formed as great volcanic islands in the Miocene period, with a depth of many thousand feet of sea-water separating them from the coasts of Portugal and Morocco, possessing a flora whose partly American character indicates that it is composed of the lineal descendants of the plants which took possession of these islands when they were first formed during the Miocene epoch. The depth of sea has prohibited land connection, and only a few waifs and strays have interfered with the original Miocene flora.

In the Malayan Archipelago, again, we have two distinct faunas and floras, almost sharply separated from one another, although only by a narrow strait of sea. This collection of very large and very small islands was once a continuous land, or rather, two continuous land masses, for India formerly extended as far as and included the island of Bali, and the Australian continent was then probably an unbroken area as far as Lombok. Both groups of islands stand upon a submarine plateau, nowhere more than one hundred fathoms deep. An elevation of the area to that height would therefore restore the ancient continental conditions. Outside this shallow sea we come almost immediately on deep water. The straits which separate Bali from Lombok are only fifteen miles across, and yet the geographical distribution of the floras (as well as the faunas) on each side is as distinct as if a wide ocean rolled between. When

what are now islands were actually two land prolongations, as above stated, this narrow strip of sea separated them, as the Straits of Dover do England from France; for the water in the straits of Lombok is considerably more than one hundred fathoms deep. The plants are Indian on one set of islands, and Australian on the other.

The flora of the West Indian Islands has a similar relationship to that of the adjacent mainland, although there is every reason to believe they have not formed an extended part of it within very recent times. The degree of difference in the flora of the various islands from that of the continent indicates how comparatively long it may have been since they became insulated. The relation of the flora of the Galapagos Archipelago to the flora of Chili has already been noted. The peculiarity about the latter volcanic islands is that they were originally peopled by straggling plants from the mainland (after the manner of the Azores). Many of the plants probably then bore conspicuous flowers, but, owing to the absence of insects, these flowers have in the meantime ceased to be showy, and have gradually assumed their present inconspicuous appearance.

The island of Madagascar, like those of New Guinea, is a land of promise to the naturalist. It is separated from the eastern coast of Africa by the Mozambique Channel, three hundred miles in width, and having deep water. It is therefore a veritable

satellite of Africa; but it has an individuality of its own as regards its fauna and flora, which has caused geologists to believe it has been separated for a long period of time, and that it may have once formed part of a now submerged land, of which the Bourbon Islands, Mauritius, Seychelles, &c., are the highest and still unsubmerged parts. Sir Charles Lyell was of opinion that Madagascar had been separated from Africa since the Miocene period. If so, then its individual flora may be a survival of that which then characterized Eastern Africa. Its fauna, especially as regards its "half-apes," has a peculiarly Miocene aspect. The dense tropical forests inland—perhaps denser than any other region in the world, from the seven months' rain which falls there every year—has been little explored by botanists; so that we know much less of the flora of Madagascar than of its fauna. Epiphytal orchids and other plants abound—an arboreal adaptation which indicates long-continued forest conditions. Some of the common and characteristic Madagascar plants are well known, as for instance the aquatic "Lattice-leaf" (*Ouvirandra*), the "Traveller's Tree" (*Ravenala*), and the state poison (*Tanghinia veneniflua*). On the Mauritius and Bourbon we have an abundance of the screw-pines (*Pandanus*), and on the Seychelles groves of the characteristic and unique "double cocoa-nut" (*Lodoicea seychellarum*).

At the commencement of the Glacial period there

is strong reason for believing that the entire area of the Desert of Sahara, in North Africa, was covered by sea. The hot, drifting sands of that great desert cover loose strata full of the shells of recent temperate mollusca, plainly indicating marine conditions of no very distant geological age. When the Sahara was a sea, it would act as a barrier against the commingling of the vegetable types north and south of it. Since its elevation into a hot desert, the broad stretch of sands has equally precluded the possibility of North and South African floral interchange. For all botanical purposes, therefore, we may regard the strip of country north of the Sahara, and extending to the Mediterranean, as a part of Europe situated in Africa. There is little difference between the general character of the flora on the European and African shores of the Mediterranean, Some species which are herbaceous on the former, as for instance the common mignonette (*Reseda odorata*), although introduced, are woody and shrubby on the latter. The Sahara is therefore a great natural barrier to the distribution of vegetation, just as the Himalayan and other mountain chains are elsewhere.

The six great natural regions into which the general distribution of animals has been grouped by Sclater and Wallace, will more or less broadly embrace the distribution of flowering plants. They are as follows :—1. The *Palæarctic* region, comprehending the whole of Europe, with temperate parts of Asia,

and those tracts of Africa north of the Sahara, just alluded to. This region includes a northerly extension from Iceland to Behring's Straits, and easterly as far as Japan. The flora is of a varied and individualized character, as we have seen, and includes every kind from Arctic to warm temperate. 2. The *Ethiopian* region, which embraces Central and Southern Africa, tropical Arabia, Madagascar, and the islands of Mauritius, Bourbon, and Seychelles. The flora of the southern part of Africa, forming the Cape "Bush," which extends from the Karoo plain to the coast, is the paradise of the whole earth for its abundance of species of attractive flowers. Its heaths (*Ericaceæ*) are known the whole world over; as are also its curious carrion-smelling *Stapelias*, its everlasting flowers (*Helichrysum*), its lilies, irisis, fig-marigolds, *pelargoniums*, *aloes*, &c. 3. The *Oriental* region, which comprehends Southern Asia from the mouth of the Indus along the southern slope of the Himalayan Mountains and the Chinese uplands to Ningpo. With this tract is associated the Islands of Formosa, the Philippines, Borneo, Java, and the Indian part of the Malayan group. Here we have distributed such well-known types as the ginger-plant, cocoa-nut, arrow-root, screw-pine, bamboo, mango, banana; yam, &c. 4. The *Australian* region, which includes Australia, New Zealand, and the southern part of the Malayan Archipelago, as well as New Guinea. There is little doubt the greater part of Australia has been

a continuous dry land surface since the close of the Secondary period, and it would almost appear as if it had been an asylum for animals and plants which lived in Europe then, but which have been driven thence by new comers. A large number of Australian plants have a notable geological association and significance. 5. The *Neotropical* region, which embraces South America, the Antilles Islands, and the tropical part of North America. Here again, in the Brazils and the extensive Amazons valleys, we have floral evidence of long-continued physical conditions like those which now prevail. Every tributary of the Amazons has a characteristic flora of its own—so long and undisturbed have been the terrestrial surroundings, which have given time for these adaptations to be developed. The immense number of *Climbing* plants, and the special adaptations to an arboreal or forest existence, are also suggestive of the ages which have elapsed during which these characters have been assumed. 6, and last, we have the *Nearctic* region, which comprehends the whole of North America, north of the tropic of Cancer. This region, like the *Palæarctic*, suffered much change and modification in its floral distribution during the Glacial epoch. Its flora therefore bears many points of resemblance to that of the latter: some species are identical; others are representative. The western part of this region has perhaps been longest dry land, and the least affected by important geological changes.

And from recent investigations it would seem as if a good deal of the characteristic North American flora had been dispersed thence, after the returning warmth had peeled off the snow-sheet with which the long-continued winter of the Glacial period had enswathed it. Here and there, in some of the quiet valleys, we have living outliers of the most ancient flora of the later Secondary and early Tertiary epochs (as we have already seen), in the huge *Sequoias* or *Wellingtonias*. The above arrangement of flowering plants into six great regions is, however, somewhat attenuated. Some of the natural subdivisions of such a region as the *Palæarctic* differ among themselves more than any of these six regions do from one another.

We here obtain a glimpse of the possible geological changes which have locally extinguished families of plants in one region and isolated them in another; and we have also seen how it is possible that in the keen struggle for existence which has been going on among flowering plants since the commencement of the Tertiary epoch, some have developed characters which have given them an immense predominance over their fellows, and enabled them to spread over greater portions of the earth's surface. In addition to these primarily operative causes, we have the more complex and perhaps equally important machinery for the accidental distribution of plants, in migratory birds and mammals, as well as in oceanic currents and periodic winds.

CHAPTER V.

THE STRUCTURE OF FLOWERING PLANTS.

THE life of every plant is included in the two necessary functions of *vegetation* and *reproduction.* The former is that by means of which the individual plant lives and grows—the latter that by which it perpetuates its own kind. As these two functions differ so greatly in their nature and operation, it follows that the organs of the plant which fulfil them must differ from each other accordingly. In flowering plants these organs are popularly known as *leaves* and *flowers.* In shape, usually in colour, and in position they are each distinct. The size of the plant has nothing to do with this differentiation of organs according to the duties they have to perform. It is as perfect in a cowslip as in a chestnut; and its universal operation shows how important this division of labour is to the well-being of plants.

At first sight it seems difficult to reduce the multiplicity of organs in plants to anything like unity. Roots, stems, bark, leaves, bracts, stipules, spathes, the different parts of the flowers, thorns, prickles, tendrils, aerial roots—all tend to confuse the student

by their variety of shapes, as well as by their numerical abundance. But the theory propounded by Wolff upwards of a century ago, and thirty years afterwards by the distinguished Goethe, that every flowering plant could be reduced to stem and leaf, greatly simplified the mode of regarding the organs of plants. The root is but an underground part of the stem; the leaf is but a flattened expansion of the bark. Even the rugged oak tree, whose gnarled and furrowed bark seems the very antithesis of a leaf, can easily be proved to be organically related to it. If we trace the bark-covering away from the trunk, along some huge primary branch, and on to the secondary and tertiary branches which shoot from it, we presently find ourselves following the green skin which covers the young and tender shoots of the present summer, and eventually we come to where this delicate bark flattens out into the variously-shaped expansions we call leaves. The floral organs, such as the sepals of the calyx, the usually bright-coloured petals, stamens, and pistils, all are only so many modified leaves. In the leaf-buds, up to a certain stage of development, we can artificially cause either flowers or leaves to be produced. Every horticulturist is aware of this fact, and not unfrequently takes advantage of it. Gardeners, by *crippling* the plants, can thus force their *azalea* or *camellia* buds to burst forth into flowers instead of into leaves. Pruning and "ringing" fruit-trees is resorted

to for the purpose of developing flower-buds, instead of leaf-buds, for the sake of the fruit. It would thus appear as if floral organs were less highly organized than green leaves, although we are in the habit of regarding the converse as true. There can be no doubt, however, that the parts of flowers, in spite of the special adaptations they subserve, are really less complex as to structure. It is perhaps on this account it is possible to produce such a marvellous variety of shapes, and especially of tints and colours, in floral organs. If they had been more highly organized, their plasticity might not have been great enough to have allowed of those wonderful variations of floral shape and colour which we behold. Anyone examining a petal under the microscope can easily see how simple is its cellular structure as compared with that of a leaf from the same plant. The structure of the stamens and pistil is even more loose and cellular, whilst the pollen-grains are seen to be merely simple detached cells, and nothing more. The number of flowers which a plant bears in a natural state always has a relation to the richness of the soil. If the latter be great, there will be an abundance of leaves; if poor, a larger proportion of flowers. Leaf-buds are generally produced in excess when a plant is *over*-fed; flower-buds when it is *under*-fed. This proves, what indeed all physiologists are agreed upon, that reproduction is of a simple and not a complex character. There is little difference between the

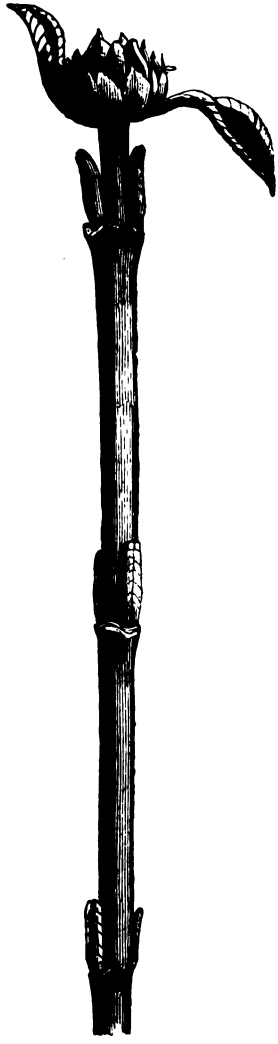
Fig. 7.

Leaf-buds of Horse-chestnut.

Fig. 8.

Leaf-buds of Ash.

Fig. 9.

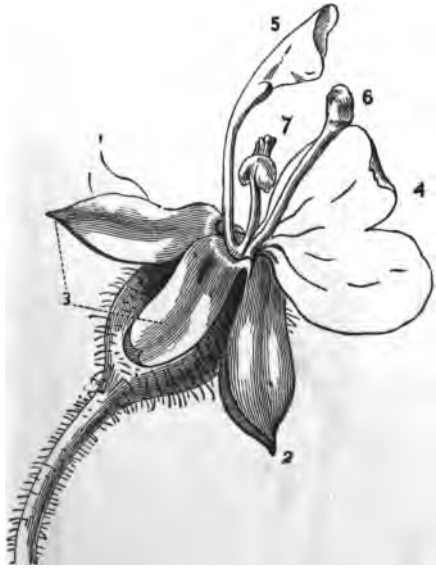


Leaf-buds of Wayfaring Tree, showing terminal whorl structure.

actual mode of fertilization in a sea-weed or any other cryptogam, and that of a true flowering plant.

In some plants the relationship which the floral organs bear to true leaves is plainly seen; in others it is more obscure. But it is possible to intercalate in a series every shade of difference between one extreme and another. Perhaps nothing more plainly shows the modified leafy character of specially repro-

Fig. 10.



Enchanter's Nightshade (*Circea lutetiana*) with one stamen (5) partly converted into a petal.

ductive parts of flowers, such as stamens and pistils, than the monstrous flowers which are so frequent

in our gardens. In the common rose, for instance, the five sepals will sometimes be developed into the

Fig. 11.

Peach, showing sepals and petals altered into true leaves.

peculiar pinnated leaves characteristic of this plant. The numerous stamens often lose their character, and

Fig. 12.

Bracts of *Plantago coronopus* altered into leaves.

become petals or are petaloid; and in the case of varieties of roses which have been long under garden cultivation, such as the "cabbage rose," some of the petals will actually assume the leafy shape and structure even to its greenness. Another not uncommon monstrosity in the rose is the development of the pistils into a leaf-bud, borne on a special stalk in the heart of the flower. Here we have decided reversions to leafy characters, which plainly prove to the botanist that all the floral parts of flowers, without exception, are modified leaves. We have seen that this modification is not from a lower to a higher structure, but the converse.

The functions which leaves usually perform for the plants to which they belong is that of obtaining food. Their under surfaces are crowded with immense numbers of *stomata*, or mouths, formed of loose cells, which cause the apertures to open and close with heat and cold. In at these mouths the slight admixture of carbonic acid in the atmosphere, cast into it from the breath of animals, or given forth from volcanoes and other natural sources, is carried along with the air it has polluted. The cellular structure of the parenchyma at the under sides of leaves is usually looser than at the upper. The air can therefore circulate through the cells, where chemical decomposition goes on, the carbon being absorbed and the oxygen previously combined with it set free. This is done under the stimulancy of sunlight only, for the process

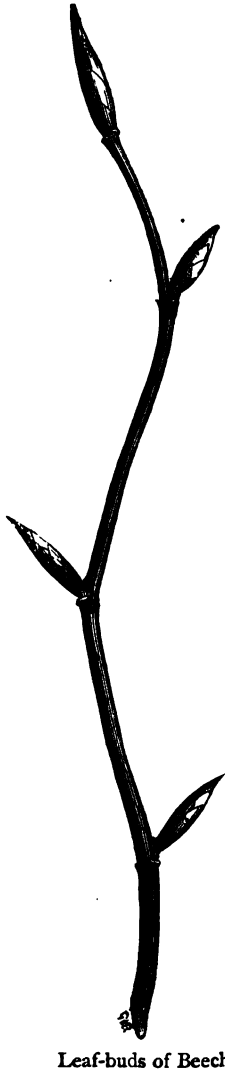
not only ceases by night, but the reverse action of slightly giving forth carbonic acid then takes place. In aquatic plants, whose floating leaves rest upon the water, the *stomata* or breathing mouths are usually situated on the upper surfaces, for the lower being in contact with water could not possibly have utilized the breathing mouths usually situated there.

This decomposition of the carbonic acid of the atmosphere has been rightly regarded as a most simple and perfect adaptation between the animal and the vegetable kingdoms, for the mutual benefit of each. The millions of tons of carbon annually poured into the atmosphere are as constantly withdrawn by plants of all kinds, except fungi, and stored away into their tissues. Our coal, lignite, and peat-beds represent the excess of solid carbon which floated in the atmosphere during periods previous to the present, and which has been thus stored away in the mineral condition. In order that leaves may the better perform this doubly important function of assimilating the carbon, it is necessary for them to be so placed along the branches or stalks of the plants as not to interfere with each other. It is important to remember that the stimulating effect of sunshine is absolutely necessary for the leaves to act healthily and vigorously. Hence the most perfect plants are those which have the leaves so arranged as that each and all get the maximum of sunshine, as well as the largest space of atmosphere to be suspended

in. The modes of attachment and arrangement of the leaves of plants always have reference to these opportunities for the leaves best to do their work. And the different shapes of leaves, their sizes, their elevation upon the parent plant above the ground, and numerous other characters, many of which have become distinctive of orders and genera, can be best understood from this point of view. Thus, as a rule, the majority of our grasses simply mat the ground, where all the leaves are bathed in sunshine during the day. Only the flower-stems rise perpendicularly, on account of the necessity for the wind to be able to take up and carry away their pollen. Plants with larger leaves have the latter lifted on stems above the ground, and some thus attain the magnitude of forest trees. But even among living species, to say nothing of extinct forms, we have every shade of transition *in size* of flowering plants, from the marsh pennywort to an oak tree.

The method of arrangement of leaves on plants is exceedingly simple, and yet almost mathematical in its character. All are arranged in *spirals*. The spiral direction is that taken by a stone thrown into deep water. It is also that adopted by a climbing plant. It is the *line of least resistance*. Sometimes in plants this spiral is modified, but the student never fails to see that only the idea of a spiral arrangement will account for all the facts. This method is called *phyllotaxis*, or "leaf succession." Perhaps it can be best

Fig. 13.



Leaf-buds of Beech.

Fig. 14.

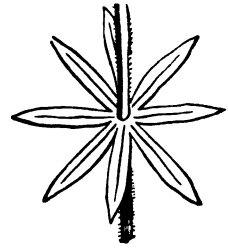
Leaf-buds of Hornbeam, showing phyllotaxial arrangement.

understood by referring to the childish amusement of rolling up a long strip of drawing paper into a close coil. On thrusting outwards the central portion of this, we can draw forth the entire length into a long spire along which the paper winds spirally. When we have pulled out the toy to the utmost, we can then depress it, at will, to any degree of shortness, or even shut it up altogether. Let us suppose this elongated spiral to represent a branch or stem, then, if the leaves are supposed to be growing along the upper edge of the paper all the way up, it would represent their *phyllotaxy*. It is evident that we could arrange any number, that if the leaves were to be large, there would only be room for few of them; if small, arrangement could be made for more according to their size. The spiral could be drawn out to its utmost length, to allow as many large leaves as possible to be attached. Or it could be depressed, until eventually all the leaves came close down together, so as to form a dense rosette, one leaf overlapping another. The places where the leaves are fixed would be called *nodes*, and the spaces between them *internodes*. So that the act of drawing out the spiral, or of depressing it, would be simply to make the spaces or *internodes* longer or shorter, or to abolish or depress them altogether, and thus form such a rosette arrangement as we get in the leaves of the common daisy. Or only some of the internodes may be suppressed, and a few left, and then we should have the *verticillate*, or star-like,

1. COLUMBINE. *Aquilegia vulgaris. cold. calyx.* 2. MARSH MALLOW. *Althæa rosea.*
3. FLAX. *Linum usitatissimum.* 4. HORNED POPPY. *Glaucium luteum.*

arrangement of leaves, such as we get in the sweet wood ruff, and cleavers (*Galium aparine*). Thus, we commence with a certain leaf, and allow the finger to trace the rest up the stem in succession until we come to one immediately over that from which we started. We should thus have completed a perfect spiral, and have passed a greater or less number of leaves on the road. This number could be expressed in figures, together with the number of times the finger travelled round the stem before it came to the upper leaf which completed the spiral. Thus, if we passed four leaves, and went round the stem only once before we came to a leaf standing above that from which we began, the *phyllotaxy*, or "leaf succession" would be expressed as one-fifth. If we had to wind *twice* round the stem before we found a leaf exactly over that we commenced with, and passed say eight leaves on our way, it would be expressed as two-ninths, and so on according to the number of leaves passed, and the number of times we had to spirally ascend the stem. If we allow a climbing plant, like the convolvulus, to climb an upright pole, in its spiral ascent it will give out leaves, which make the bare pole appear as if separated into nodes.

Fig. 15.



Verticillate Leaves of Woodruff.

The reader has only to compare the small number of leaves found in the spiral of the horse-chestnut, plane, or other large-leaveed tree, to see that the large

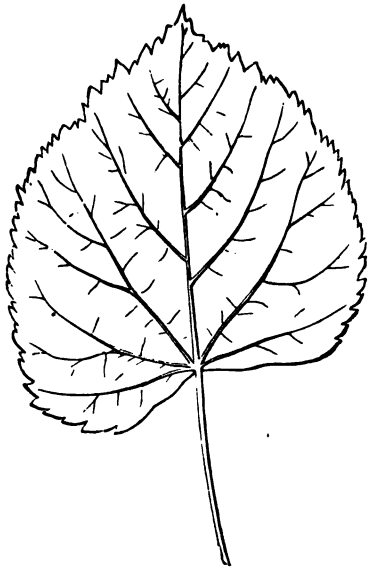
Fig. 16.

Bindweed spirally climbing an upright support.

size of the leaves is somehow related to the fewness of their occurrence. Were they more numerous they

would defeat the end for which they are intended, and be in each other's way. On the other hand, when we examine the leaf-spiral of such trees as the spruce, larch, and other conifers, we are surprised at the closeness of the spiral and the dense manner with which it is packed with leaves, giving to the bark to which they have been attached quite a quincunx appearance.

Fig. 17.



Unequal-sided Leaf of Lime Tree.

This number is easily accounted for, however, when we remember the smallness of the needle-shaped leaves. In some trees, as the lime, for instance, the

leaf is unequal-sided, one side being much larger than the other. It will usually be found that the larger half of the upper leaf is that which shades the smaller half of the lower. The reason why large leaves are lobed (as in the horse-chestnut), or palmate, (as in the plane), may be to allow the light to pass through the upper and usually dense foliage, and for a completer circulation of air to be effected. It is certain that these benefits must result from such an arrangement.

Not only do the spaces or internodes between the places where the leaves spring become shorter towards the upper and terminal parts of plants, but the leaves also are usually smaller in size, and not unfrequently different in shape. This is due to their being farthest removed from the sources of nutrition. Mr. Herbert Spencer shows how strikingly this is the case with the leaves of the common bramble. In some plants the upper internodal spaces are almost entirely suppressed. Now if the sepals and petals of flowers are only modified leaves, we can see how it may have been brought about that they should all be fixed on the same plane, viz. by the complete suppression of the internodes. And as flowers are usually found terminating a stem, or are borne on foot-stalks which spring from axils, it follows that they are always farthest removed from the main sources of nutrition, and are therefore situated where leaves would soonest become aborted in their spirals as well as in their

sizes and shapes. It is a suggestive fact to the botanist that among the first conspicuous flowering plants to appear in geological order are the *Proteaceæ*, found in the Upper Cretaceous beds, and abundant in the Eocene strata, as we have seen. They included *Banksias*, *Dryandras*, *Hakeas*, &c.; which usually derive their really attractive appearance from the coloured bracts which occupy the place of true petals. In *Banksia*, notwithstanding the beauty of the flowers, the latter are in reality *apetalous*, that is, do not possess true petals, although the flower-head is dense and cone-like from the number of often brilliantly coloured bracts. The latter perform the functions which the coloured petals of true flowers subserve. They attract insects, which are rewarded for their trouble of visiting the flowers by the store of honey some of them contain. Here we see the least degree of specialization in the floral parts, and, suggestively enough, this is characteristic of the most ancient conspicuous flower-bearing plants known to botanists and geologists. It indicates how attractive floral organs may have been developed. In such plants as the *Poinsettia*, a South American euphorbiaceous shrub, much cultivated in our greenhouses for the sake of its brilliant crimson terminal leaves, which contrast strongly with the deep green of the rest, we have a singular modification of true leaves, so as to enable them to perform the functions otherwise fulfilled by petals. These upper and terminal leaves

differ somewhat in size and shape from the rest, and may be regarded as bracts, although the leaf variation is plainly visible. Their internodal spaces are nearly suppressed, and so they form a whorl, exceedingly showy in character, which must effectively attract insects to the reproductive parts in the centre. The latter are furnished with open nectaries full of honey. In the south of Spain the *Poinsettia* will grow in the open air, and is there as conspicuous an object in gardens as it is in those of the West Indies.

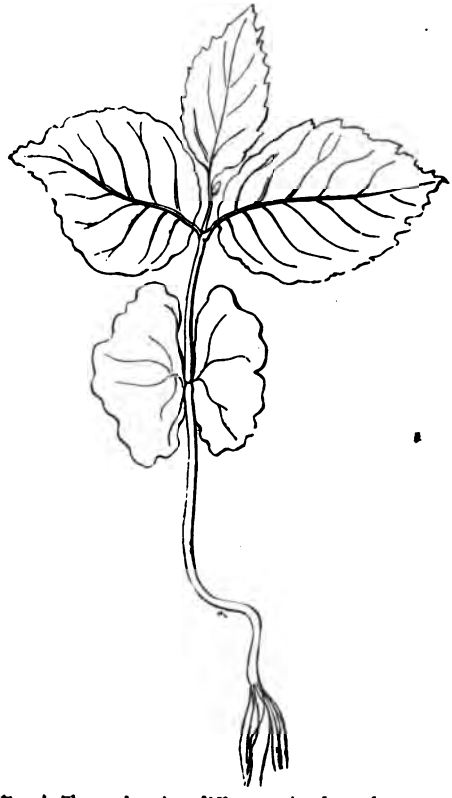
The different number of sepals and petals which characterize various flowers, may thus be ascribed to the difference in the leaf-spirals from which they were originally modified. The numbers five and ten occur perhaps more frequently in the petals of dicotyledonous flowers than any other, whilst three and its multiples are the normal figures in the external parts of monocotyledonous flowers. The stamens are uniformly the same number as the petals, or a multiple of them, showing that they have been aborted from one or two leaf-spirals, as the case may be. The pistil represents the terminal bud of the branch the most remote from sources of nutriment, and therefore most cellular in structure. Its carpels, sometimes separate (*apocarpous*), and sometimes growing together (*syncarpous*), are in this condition analogous to that in which we find the petals, which are separate (*polypetalous*), or united into one piece or bell (*gamopetalous*). The closed carpels, with their included seeds, represent a leaf folded up

from the midrib. But, although the pistil and ovary are the upper and last aborted of all the foliar organs, and have a structure simpler at first than that of the other organs, this is only in the early stages of the flower. The petals and stamens wither as soon as they have performed their short-lived functions, and the nutriment they absorbed from the plant is then transferred to the pistil, which is thus enabled to grow and develop its fruits or seeds.

It is a common popular error to find the spores of mosses, ferns, and other cryptogamous plants compared with the seeds of true flowering plants. Spores, however, are simple cells. They rarely give immediately rise to plants, but to an intermediate condition, which takes up and completes the reproduction. In ferns the result of spore germination is the formation of the *prothallus*, and the latter in reality has to reproduce the plant. A spore, therefore, is comparable with a *pollen-grain*, and the mode in which the latter gives out its pollen-tube is thus seen to be equivalent to the spore forming a prothallus. The anther, or pollen-bag, which always forms the upper part of the stamen in flowering plants, is the equivalent of the bag which contains the spores in mosses and ferns, and which goes by the name of *sporangia*. Thus, it will be seen that as regards the actual structure of the fertilizing organs, *cryptogamous* plants are not so entirely different from *phanerogamous* plants as has been imagined.

The difference in the *shapes* of petals of different flowers is frequently (but not always) in proportion to

Fig. 18.

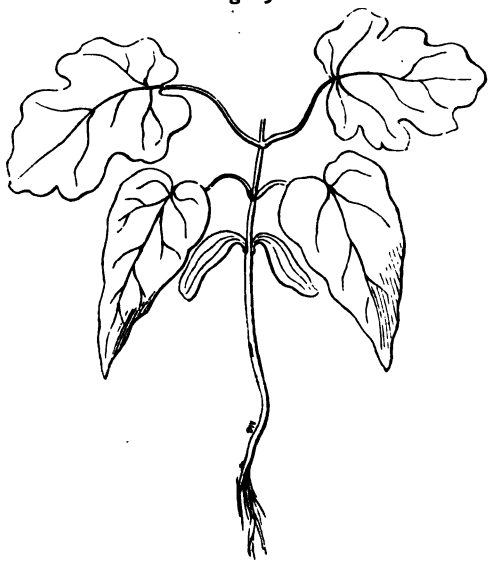


Young Beech Tree, showing difference in shape between true and seed leaves.

the degree of difference in the leaves of the same plants. Both flowers and leaves have undoubtedly

been modified in different directions since they originated, and this may account for the above rule being of rather loose application. Flowers, we know, have been considerably modified in shape by their adaptations to insects, and leaves may have adapted them

Fig. 19.



Young Sycamore Tree, showing cotyledon and first and second pairs of leaves.

to the physical conditions of growth. Thus, much as the leaves of different plants may vary from one another, we generally find that the first or *radicle* leaves of the same plants resemble each other more than the later formed ones do; the *radicle* leaf being perhaps

more nearly related to the common ancestral form. That leaves as well as flowers are frequently narrowed in their adaptations to special conditions of growth, we see particularly exemplified in aquatic plants. The water crowfoot (*Ranunculus aquatilis*) has the

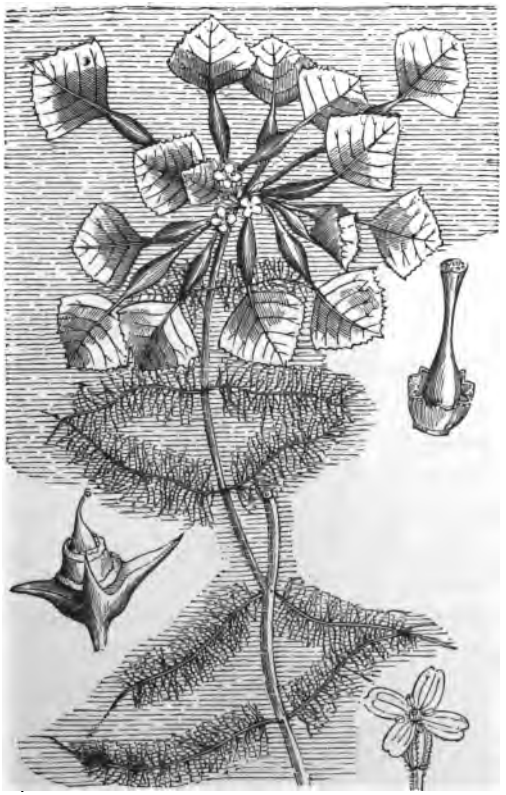
Fig. 20.

Water Crowfoot (*Ranunculus aquatilis*), showing submerged and floating leaves.

fine thread-like submerged leaves immersed in water, and broad, roundish leaves floating at the top. The arrow-head (*Sagittaria sagittifolia*) has also two kinds of leaves, one slender and submerged, and the other whose arrow-headed shape gives to the plant its name,

are borne on long stalks, and stand clean out of the water. Most of our British aquatic flowering plants

Fig. 21.



Trapa natans, showing difference between floating and submerged leaves.

have thread-like leaves, as *Myriophyllum*, *Hippuris*, *Utricularia*, and others. Leaves also have been wonder-

fully modified to serve some other advantageous ends in the economy of the plant than those of mere food-suppliers. They act as tendrils in the pea, and twine

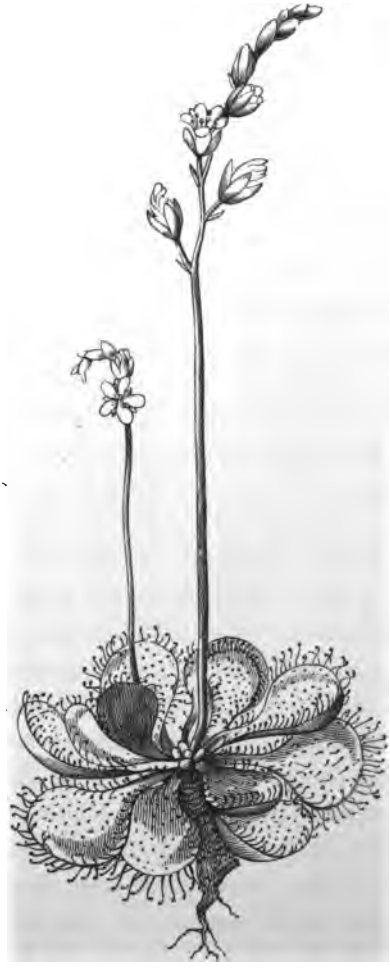
Fig. 22.

Pitcher Plant (*Sarracenia*), a "carnivorous" species.

round the plants whose woody or otherwise strong stems enable them to rise erect by their own strength.

In this manner they enable the pea to rise to a height it otherwise could not have done, and so economize the growth of the plant, there being no necessity to form tissue which shall be strong enough to give it an independent erectness. The force which might have been required for this purpose is therefore utilized to form the albuminous supply of food stored up in the two lobes or cotyledons of the seed, by means of which the young embryo can be kept alive for a longer period, and thus be enabled to more certainly strike root when it is strong enough to do so. Very frequently leaves are aborted into bracts, to serve as protective envelopes for leaf and flower buds. Or some of the leaves may be protective to the plant, generally against foes, as for instance in the spines of the berberry. In the pitcher plants (*Nepenthes*, *Sarracenia*, &c.) some of them grow together along their margins to form a tube, on whose inner surfaces is secreted a fluid capable of digesting the animal matter of captured insects, and of assimilating the nitrogenous material. One of the occasional "monstrosities" of broad leaves is to have their outer edges grow together in the bud, so that they form a partial tube or pitcher, like that of the *Sarracenia*. In the leaves of the sundews (*Drosera*) the hairs covering the surfaces of the leaves have been developed into special glands, which secrete the viscous substances in which small flies are entangled, whilst the surface of the leaves can afterwards assimilate their animal

Fig. 23.



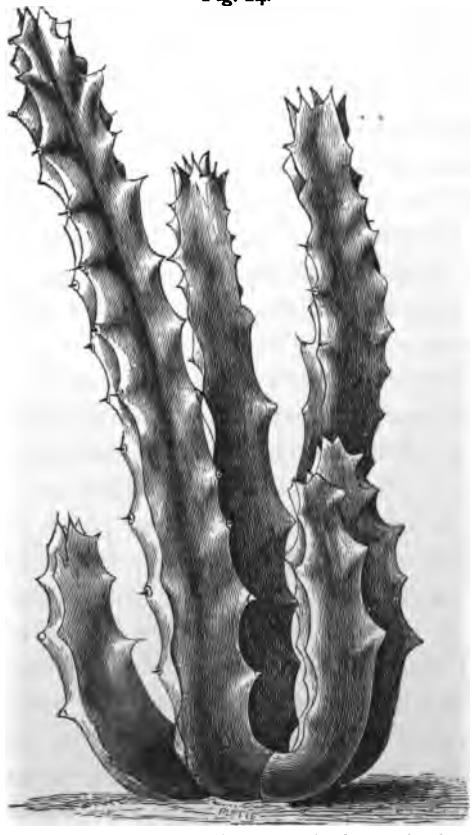
Round-leaved Sundew (*Drosera rotundifolia*).

matter. In the butterworts (*Pinguicula*) the slimy secretion produced by the entire surface of the leaf performs a similar function. It is to be noted that these plants usually grow on the surface of the *Sphagnums* which cover boggy or marshy places. Their roots do not usually extend into the ground, but are used simply to anchor or fix the plants to one place; hence the roots cannot absorb the necessary salts required for the well-being of the plants themselves, so that the duty is thrown upon the leaves.

It is doubtful whether even the simple division of flowering plants into stem and leaf may not be reduced to a simpler formula still. Thus in some of the cactuses (*Phyllocactus*, for instance) the stem not only assumes a flattened, succulent, leaf-like appearance, but actually performs the functions of leaves, whilst the true leaves are specialized to form the protective prickles with which these plants are armed. One genus of *Euphorbia* mimics or assumes this well-known cactus-like shape. In the Australian *Acacias*, as well as in our Butcher's broom (*Ruscus*), the footstalk of the leaf is flattened out into a broad surface, is covered with stomata or breathing mouths, and, in fact, does duty for the leaf—the latter being very small and feebly developed. In the arum, potato, &c., the underground part of the stem develops those specialized food masses, called tubers, whence new plants can germinate and live on the stored-up supplies thus provided for them. Such plants have two

modes of reproduction, and the duty usually performed by the floral organs is in this way consider-

Fig. 24.



Euphorbia, simulating the characteristic shape of a Cactus.

ably relieved. The process is analogous to that in vogue among such lowly organized animals as the

Hydra, where we have budding as well as eggs produced, both of which alike reproduce the species. In the strawberry the same end is compassed by the *stolons*, or creepers, from whose joints new plants are developed.

It will be seen that notwithstanding the immense diversity and variety in shape, size, and number of the vegetative and reproductive organs of plants, they are so many modified units, adapted to various conditions of growth, biological and physical. Nothing impresses the reverent student of nature more than the fact that where there appears the greatest opportunity for accident to occur, law is most absolute and imperative. Our ideas of the organic world are thus elevated to a higher station for contemplation, and produce a more appropriate conception of the Cause which nurses and fits every member for taking its part in the "great battle of life"!

CHAPTER VI.

THE RELATIONS BETWEEN FLOWERS AND THEIR PHYSICAL SURROUNDINGS.

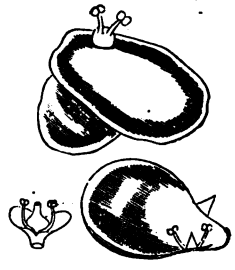
FROM a general description of the nature and relationship of those organs of reproduction in plants popularly termed "flowers," it will be seen that all the existing modifications of the floral world are so many departures from the simple and primitive type. Naturalists believe that these alterations are in the direction of *specialization;* that is, of producing a number of types of flowers, instead of one, each adapted to a certain set of conditions, biological and physical. These types are known as "orders," and as such botanists speak of them. Every *order* has usually a number of genera, or specialized groups, which differ among themselves, but always within certain limits. These again include a number of *species*, which possess an individuality of their own, although this does not destroy that evidence of relationship among them by means of which botanists are enabled to group them in genera. Nearly every species has *varieties*, which depart from the specific type to some degree. These varietal changes in flowers are actually going on around us every day.

The changes which produced *species* occupied longer time to accumulate that difference between one set of plants and another which would be regarded as *specific*. To create a *genus* it is required that species should undergo changes analogous to those which mere varieties experienced; and here again, a still longer lapse of time might be taken up in the process. Whilst, to form an *order* of flowering plants, the changes have to be correspondingly important; so that we may rightly regard it as occupying periods long enough to be geological in their duration.

We cannot tell which were the first flowering plants. The grass family certainly made their appearance early in the Secondary epoch, and we have already seen that the mode of appearance of flowering plants has been in the order of their increasing floral complexity — simple types first, and specialized forms later. We know that the different groups of cryptogamous plants, such as horsetails, club-mosses, ferns, &c., were specialized before flowering plants appeared, with the exception perhaps of the conifers. It does not follow, however, because we usually regard flowering plants as higher organized than non-flowering or *cryptogamous* plants, that the highest type of the latter is always less organized than the lowest order of the former. Naturalists have great difficulty in arranging either animals or plants in an *ascending* series, according to their importance. Every day they are seeing more plainly that they are related by diverging

as well as ascending lines. Thus, although the *Lancelet* is placed among the vertebrate animals and occupies the lowest order of fishes, it does not follow that it has a complexer or higher organization than the cuttle-fishes, which stand at the head of the invertebrate animals. On the contrary, we know that the Lancelet is in every way a simpler and more rudimentary type. So with the similar relation of the highest cryptogamous plants, as ferns, and the lowest of flower-bearing or phænogamous plants, as the duckweeds (*Lemnaceæ*). We can hardly conceive any kind of plants to be simpler in structure than the latter. They scarcely require the twofold division of *stem* and *leaf*, which are usually regarded as entering into the construction of all flowering plants. Their structure is cellular, and some species seem to depend a good deal more upon budding for their propagation than upon seeding. They are either rootless, or have slender roots tipped with spongy ends, hanging from beneath their fronds. The floral organs could not be more simply arranged. There is no evidence of a whorl, for the number of stamens borne by members of the various genera and species of this order never exceeds two, and sometimes there is only one. The single pistil possesses

Fig. 25.



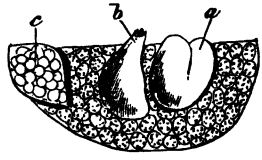
Flowers and Fronds of Greater Duckweed (*Lemna polyrhiza*). 10 nat. size.

only one ovary, and usually only bears a single seed.

We have referred to the duckweeds because their floral and foliar structure plainly indicates they are among the simplest of flower-bearing plants; and because, when compared with the ferns, it is evident they are less specialized, although they are included in the higher division of vegetation. This type of flowering plant may have been among the first to appear on our globe, although its loose, cellular structure would not be as favourable to fossilization as that of ferns or club-mosses. The present geographical distribution of the duckweeds is an argument for their geological antiquity. They are found growing in nearly all climates, although they are naturally most abundant in temperate regions, as the great heat prevailing over tropical swamps soon dries up the latter. All are fresh-water plants, and the geologist is well aware that inhabitants of such conditions have changed less in outward shapes than any other, perhaps because lacustrine or fluviatile conditions must always be similar. At any rate, he finds it difficult to draw any vivid distinction between the fossil *Anodonta*, which abounded in the Upper Devonian lakes of Ireland, and the swan mussels (*Anodon*) which are to be found in the lakes and ponds of the present day. The *Paludinæ* of the Purbeck marble resemble in almost every character those which are still abundant in fresh water. This striking fact of fresh-

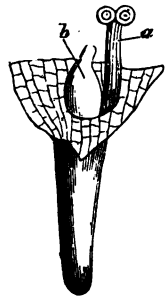
water organisms undergoing so little change during immense epochs, when coupled with that of the wide-spread distribution of the *Lemnaceæ*, is an argument in favour of the geological antiquity of the latter, and of the possibility of their being among the first flowering plants to appear. One British species, *Wolffia arrhiza*, enjoys the distinction of being the smallest known flowering plant, its fronds being only the twentieth part of an inch long, and the fortieth part broad.

Fig. 26.



Wolffia arrhiza (magnified).

Fig. 27.



Grantia microscopica (magnified).

It is a notable fact that the simplest types of flowering plants affect aquatic or semi-aquatic habits. This is the case with the starwort (*Callitriche*), a not uncommon plant in clear water, and usually a favourite in aquaria, whose oppositely-arranged leaves have such small internodal spaces that their dense arrangement gives the plant the stellar appearance which has obtained for it its popular name. The flowers, like those of the duckweeds, are exceedingly minute and primitive in structure; and even a botanist has sometimes a difficulty in identifying them.

The flowers are male and female, the former being represented by a single stamen, protected by two bracts. The female flowers have a double-styled

Fig. 28.

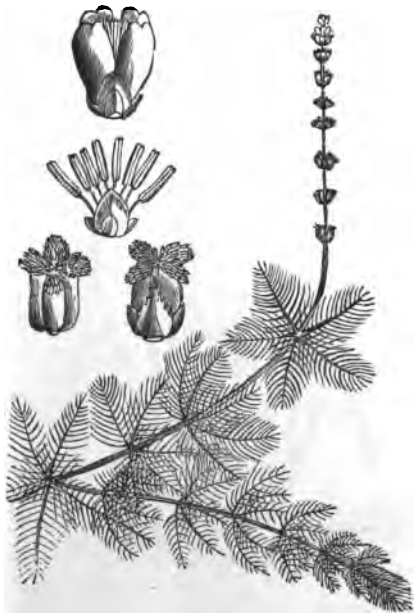
Starwort (*Callitriche verna*), with details of floral structure.

pistil, and a four-celled ovary, indicating more specialization than is perceptible in the male flowers. Like the duckweeds, the *Callitriche* is found living in rivers, ponds, and lakes in most parts of the world;

and the argument we endeavoured to draw from the former, as to their primitive structure, distribution, and probable geological antiquity, will apply to the starworts almost as well. In some instances, the differentiation between the male and female flowers is obliterated by the former producing ovaries. *Zanichellia* is another genus of aquatic plants which bears small and imperfect flowers, having a single stamen, and a more elaborate pistil. *Zostera* is the name given to a genus of marine plants, belonging to the monocotyledons. It has always obtained some notoriety for the singularity of its habitat, which is the hard muddy parts of the *sea*-bottom, at no great distance from shore. In this respect its growth is analogous to that of the pondweeds (*Potamogeton*) and millefoils (*Myriophyllum*) of our lakes. Its bright green, grass-like leaves are often to be seen matting the sea-bed during the ebb of the spring tides. The flowers are *diœcious* — that is, they grow upon separate plants—and are usually arranged in two rows on one side of a leaf-like stalk; but they possess neither calyx nor corolla, and so far are equal in simplicity with the plants already mentioned. The style of the pistil, however, is remarkable for its two long stigmas. *Ruppia* is another genus of submerged plants, not unfrequent off the southern coasts of England, where its habits are those of a marine pondweed. In the mechanical means by which its flower-head is brought to the surface of the water,

we have a specialization which is shared by the fresh-water *Vallisneria.* The stalk of the flower is spiral, and can be compressed or lengthened, according as

Fig. 29.



Millefoil (*Myriophyllum spicatum*).

the level of the water may require. In the *Vallisneria* the spiral nature of the stalk of the female flower is well known, and it seems to be an adaptation to the frequent changes in the levels of the rivers where it grows. The male flowers of *Vallisneria* are very small, and have no stalks. When they are

thoroughly ripe, however, they are detached, and float on the surface. Then they come into contact with the heads of the female flowers, whose spiral stalks have been unwound and elongated in order to meet them. *Ruppia*, like many aquatic plants, has an

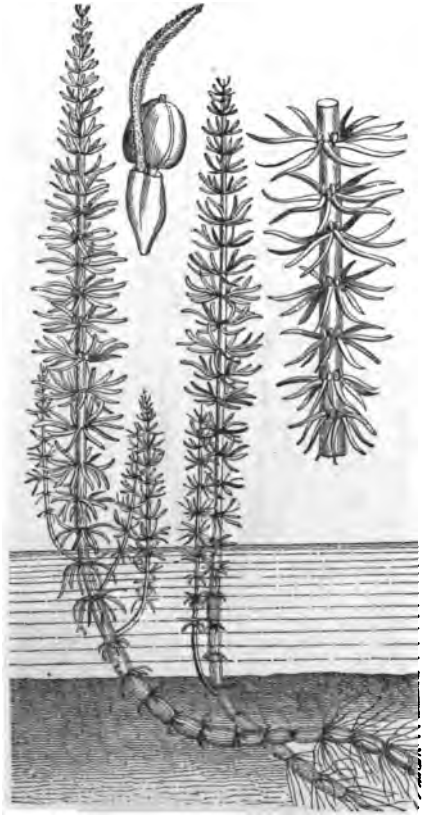
Fig. 30.

Vallisneria, showing spiral arrangement for elevating female flowers.

extraordinarily extensive geographical distribution. *Vallisneria*, on the other hand, has a very irregular dispersion ; for, whilst it is abundant in most of the warm and tropical lakes and rivers of the earth, to whose changing levels it is admirably and specially

adapted, it includes an allied species which is entirely confined to Australia.

Fig. 31.



Mare's Tail (*Hippuris vulgaris*), showing single flower magnified.

The *Hippuris*, whose external appearance so much resembles the horsetails (*Equisetaceæ*) that it is fre-

quently mistaken for those common cryptogamous plants, is another suggestive type of lowly-organized flowering plant. Its floral as well as foliar arrangements, however, indicate a higher degree of specializa-

Fig. 32.

Hornwort (*Ceratophyllum demersum*).

tion than is possessed by the aquatic plants already mentioned. Thus, the flowers are arranged in whorls, sheltered in similar arrangements of linear leaves. This indicates an incomplete separation of inter-

nodal spaces, which may have been turned to account in giving the plant its generic distinction. The flowers are scarcely less simple than those of the foregoing species, having no petals, and only one stamen each.

If popular nomenclature had to deal with the class of flowers we have been describing, it would refuse to admit them into the category. They possess none of the attributes with which the non-botanical mind associates flowers. They have neither perfume, colour, nor graceful shape to recommend them, and yet their reproductive organs are effective without these auxiliaries. For auxiliary aids we now know these qualities to be—aids which have been called into existence or developed during the life-histories of flowering plants. It would not be difficult to establish a series even of British plants, with such inconspicuous and imperfect flowers as those of the duckweed, &c., at one end, and those of bright-coloured labiate, papilionaceous, orchid, and other flowers having highly-specialized floral parts, at the other. These two extremes of attractive and non-attractive flowers would be gradually interlinked by others in which we could see the floral characters gradually developing. That the size and colour of the petals need not interfere with the more important reproductive organs, is proved by their varying size in different species of the same genus, as, for instance, in those of *Geranium sylvaticum* and *G. sanguineum*, as compared with the

minute and scarcely developed corollas of *Geranium pusillum.*

There can be no question that in every part of the world most flowering plants have gradually acquired new habits. In many instances, but not all, these have induced some modification of the floral organs. What can be more contrasted with the general tall and upright growth of pines, than the habit which the Polar species has of trailing along the ground with feeble stem? But we can see at a glance that the latter is the only possible mode of growth in such regions. Perhaps the most evidently acquired of all habits on the part of plants is that of being *parasitical.* It at once presupposes the existence of other species on which they can prey. We say nothing of the parasitical habits of *Fungi,* especially of those innumerable microscopic species whose smallness is an advantage to them in their predatory habits. Parasitic fungi had acquired this habit as long ago as the Carboniferous epoch, as is evident from the fossil *Peronospora,* recently described by Mr. Worthington Smith as penetrating the tissues of one of the gigantic club-mosses (*Lepidodendron*). But parasitic flowering plants must be of considerably later date. It is questionable whether this habit had been acquired long before the Miocene period; and it is certain that the number of parasitic species is greater now than it ever was before in the history of our planet. The singular fact about them is that they constitute no particular order

of plants, for we find them differentiated from widely separated genera to this peculiar habit. Thus the dodder (*Cuscuta*) is a member of a rather showy order of flowers, the *Convolvulaceæ*. Its long, thread-like,

Fig. 33.

The Dodder (*Cuscuta*). S, S, suckers.

creeping stem will intertwine the dense branches of the gorse, notwithstanding the defensive prickly leaves of the latter. It will mat together an enormous number of clover plants, and we find its stem provided with special suckers for the double purpose

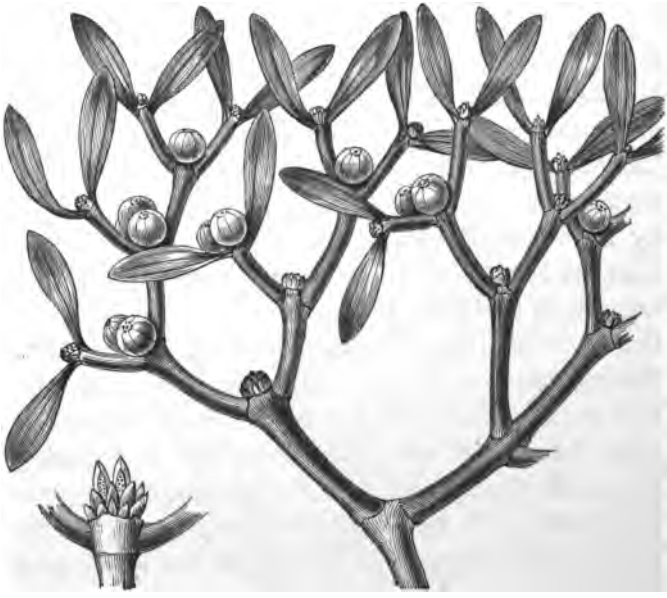
Fig. 34.

Broom-rape (*Orobanche rapum*).

of absorbing nutriment from its hosts, and keeping its position unchanged. And yet the seeds of the dodder germinate in the ground in the usual way, and live there upon the albumen stored up in the lobes, until the opportunity of seizing on their prey occurs. The broom-rapes (*Orobanche*) are upright plants, with large gamopetalous, although not very attractive, flowers. They abound in clover fields and on our heaths, their roots parasitically intercepting the nutriment absorbed by the roots of clover, gorse, &c. The toothwort (*Lathrea squamaria*) is an allied genus to the broom-rapes, with a similar parasitical habit of growing on the roots of trees, such as those of the alder. Its flowers, however, are more attractive, being purple or flesh-coloured. As the last two orders belong to the latest introduced and highly specialized of flowering plants, the *Gamopetalæ*, their acquirement of this parasitic habit must be of comparatively recent occurrence. The mistletoe (*Viscum album*) is a well-known plant, the only British species of an order which has its metropolis in the tropical regions of both hemispheres. There its congeners often bear large and brilliant flowers, although here its own are so inconspicuous. Perhaps no flowering plant has so thoroughly acquired the parasitic habit as the mistletoe. And the fact of its being unlike its brethren in its floral structure, and of its living here as a kind of "outlier," is suggestive of the long series of possible geological changes which have elapsed since it was separated

from its fellows in the earlier parts of the Tertiary epoch.

Fig. 35.

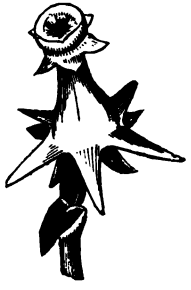


The Mistletoe (*Viscum album*).

Even among our British flowering plants we can find some genera which are sometimes wholly or semi-parasitical—such as those of *Melampyrum*, *Rhinanthus*, *Pedicularis*, &c.; and there can be little doubt that if we could compare the habits of all the flowering plants now living in the world, we should find every intermediate stage represented between the normal independent species which never indulge in the para-

sitical habit, and those that cannot now live in any other way. Most of our British wild flowers which are wholly or partially parasitic belong to the order *Scrophulariaceæ*. It is among the various members of this remarkable order that we perhaps find floral *monstrosities* more abundant than in any other—at least, such is our own experience. If this be generally true, it proves that such species must be in an unstable floral and vegetative condition, and therefore readier to adapt themselves to external conditions than the members of many other orders.

Fig. 36.



Peloric, or usual "monstrous" condition of Flower of Toadflax, having five spurs instead of only one.

Fig. 37.

Normal Flower of Toadflax.

The occurrence of *Epiphytal* plants—that is, of species which habitually grow on others, but not as parasites—is another instance of acquired habits. With the exception of such cryptogamous plants as lichens, mosses, and some ferns, this habit is perhaps more in vogue among the *Orchidaceæ* than any other

order; and especially among their tropical genera. Like parasitism it is not usually confined to any genus, but is affected by members of all alike. Some genera may include more epiphytal species than others, just as we have seen how among British plants the greatest number affecting parasitical habits belong to the *Scrophulariaceæ*. In the tropical regions the influence of physical and biological surroundings must be much more powerfully felt than in the temperate zones. The "struggle for life" among plants will therefore be intenser; and the abundant heat and moisture of tropical forests must favour the development of vegetation. We cannot be surprised, therefore, that there we find the epiphytal and parasitical habits most indulged in. The dense throng of woody trees, all growing upwards towards the light, and forming a dark canopy overhead which often prevents the solar rays from reaching the ground, is not encouraging to the growth of herbaceous flowering plants. There is neither light nor heat enough for them; and, as Wallace has remarked, nowhere in the world do we find the surface of the ground clad with such floral colours as are to be seen in an English meadow in June! But, although the conditions of tropical forests are not favourable to ground plants, they are peculiarly so to "bush-ropes" (*Lianos*) and other creepers, which twine themselves around the strong stems of other trees until they not unfrequently throttle them, prevent the upflow of sap, and thus

literally strangle them to death. Upwards the persevering climbers twine, until they at length reach the sunlight, and then break forth into dense bunches or rosettes of green leaves, and clusters of the most brilliant flowers.

The epiphytal orchids are not so ambitious. They attach themselves to the bark of some forest tree, asking nothing but a mechanical resting-place more favourable than would be found on the ground, where they would have to compete at an undue disadvantage with ferns and other plants, to which such a habitat is a vegetable paradise. But, firmly attached by their peculiar sucker-like bases, or whitish-green aerial and creeping roots, which trail down the trunks of trees and absorb such organic matter as they can, at various heights above the ground the epiphytal orchids enjoy the breeziness of their situation; and the entire force of their vegetative energy is now thrown into the development of their wonderful floral organs. Many of them give out the sweetest odours, and as these are constantly emitted whilst the flower is actively open, it must be at the expense of the vegetative energy of the plant. Such a position as theirs is also favourable to their being easily seen by forest insects, particularly the *Lepidoptera*, which love to flitter up and down the forest paths. Amid the comparative gloom and sombreness of the surroundings, the large coloured corollas of the epiphytal orchids flash like gems. And these plants are always most abundant in

the forest openings or paths, up and down which the gaily-coloured butterflies love to wander.

We are not aware of any *fossil* orchids having been found in that otherwise wonderful storehouse of Miocene plants, the Swiss *Molasse*. Orchids are highly differentiated monocotyledonous plants. Their near allies the lilies have been in existence for ages, geologically speaking; and but little modification has taken place in their structure. But the orchids have become so highly differentiated that almost every species has its own mode of fertilization, and not unfrequently has narrowed itself to one set of agents in carrying it out. The floral and staminal machinery of orchids, and the various "contrivances" for causing the pollen of one plant to be carried to stigmatic surfaces of another, when explained by such men as Darwin, reads like a fairy tale. Nowhere else in the whole world of plants do we find adaptation so peculiar, or intention so manifest. Had the orchids been highly rational and conscious beings, fully aware of the laws and relationships of biology, organic chemistry, and mechanics, they could not have adapted themselves more admirably to their natural surroundings than as we everywhere find them! And when the entomology of each locality where orchids are found is thoroughly known, there can be no doubt our cause for admiration will be increased instead of otherwise. Indeed, as regards the perfection of their floral machinery, we consider that orchids stand at the head of flowering

plants, notwithstanding their monocotyledonous character.

This complex floral structure and frequent epiphytal habits suggest to the thoughtful botanist that evolutionistic agencies must have been at work, perhaps during a long period of time, in bringing about such perfect adaptations. Some tropical forests, as those of the valleys of the Amazons and its larger tributaries, are comparatively *primeval;* that is to say, they date so far beyond the period when man appeared on the earth, that we may employ this term for comparison's sake. The latter country may have been a continued dry land surface during the entire Tertiary epoch, for such main and tributary valleys as we there find scooped out by atmospheric action, must have required enormous periods of time to fashion them. Besides, we find no evidence in the shape of marine formations of any subsidence beneath the sea-level having taken place. We can therefore understand why each tributary valley of the Amazons, as well as that of the Amazons itself, should have a distinctive flora of its own. For here terrestrial conditions have allowed of vegetative evolution, and the physical surroundings of heat and moisture have been favourable to support an intenser battle of vegetable life than elsewhere. No wonder, therefore, that naturalists should speak of the natural history of this region, animal and vegetable, as peculiarly *arboreal.*

The list of general examples of acquired habits is far from exhausted, and our desire is to be simply suggestive of the principle. Otherwise we might draw attention to the aloes and cactuses, as illustrations of adaptation to *desert* conditions quite as striking as those we have been considering. The succulent, leaf-like development of the stem, and the modification of the leaves into protective spines, which we find in the abundant and always heat-loving species of *Cactus*, are remarkable evidences of the acquirement by an entire order of characters peculiar to itself. The various extreme habitats affected by other plants—hot and sandy, as in the Spurreys, soda-loving, as in various succulent maritime species; even *Arctic* and *tropical*, or cold-loving and heat-loving—all such habits must have arisen since flowering plants first came into existence.

We need do little more than hint at such acquired habits as is possessed by the common ivy, of throwing forth adventitious roots from its stem in order to obtain support, of the twisting stems of honeysuckle, convolvulus, &c., due to one side growing a little faster than the other so as thus to develop a spiral or twisting growth: or to the *aerial* roots of such orchids as the *Vanilla*, and other well-known tropical plants and even trees—the said "aerial roots" becoming stems when they reach the ground, and doing all their duty as such, contributing to the support of the plant, and enabling it to creep and extend itself.

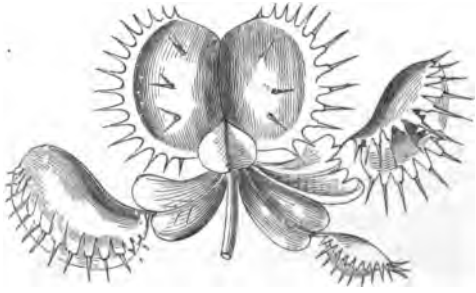
Even more specialized in their character is the group of plants, culled from various orders, which are now termed "carnivorous" and "insectivorous." None of the wonderful results of modern botanical investigation have been more startling than the discovery that there existed plants which had turned the tables on the animal kingdom, and were actually *carnivorous!* The marsh-loving habits of most of these plants, both British and foreign, show that they usually grow in places where their roots can absorb but little if any nitrogenous material. This duty is therefore thrown upon other parts of the plant, some of which are normally in the condition that the spongioles of the roots are; so that when decomposing animal matter lies in contact with them they can absorb it. Darwin's recent work on this subject has arranged the facts in a simple and easily understood manner for the student, who will there see that even in our British flora we have species possessing this carnivorous habit in varying degrees, from the occasional practice to the confirmed habit. Such a comparison bears out the theory that the carnivorous appetite on the part of all plants is an *acquired* one. In many species

Fig. 38.

Pitcher of *Cephalotis*, a carnivorous plant.

parts of the plant, generally the leaves, have been highly specialized, not only to digest and assimilate animal matter, but to catch and retain the insect tribes which furnish it. Such is notably the case with the pitcher plant (*Sarracenia, Nepenthes, Cephalotis*, &c.), as well as with the Venus fly-trap (*Dionœa muscipula*) and our common sundews. Few botanists

Fig. 39.



Leaves of Venus Fly-trap (*Dionœa muscipula*), showing spines in centre on which insects are impaled.

now contend that such adaptations as the above-mentioned were originally created as we find them. With the constant change in the physical surroundings there would be required a constant strain of creative energy, and this, in fact, would be *evolution.* Paley's argument of the watch would have been more effective if he had selected a *chronometer* instead. For in the latter he would have found internal mechanical adaptations which would enable the watch to keep correct time, either when subjected to the ex-

treme of Arctic cold, or the intensity of equatorial heat! So with the subtle arrangements of the animal and vegetable kingdoms, their constant adaptation to their external environment of physical geography has been one of the chief causes of their upward and progressive development.

CHAPTER VII.

THE RELATIONS BETWEEN FLOWERS AND THE WIND.

THE discovery of the intimate relationship between flowers and insects promises to revolutionize many of our old ideas of botany. Within the last seven or eight years a wonderful light has been thrown upon the shapes and colours of flowers, as well as on their floral mechanism generally. And as a consequence of the new views, much has been noticed and discovered concerning the structures of flowers, about which, it was generally believed, all was already known that could be known. Thanks to the researches of Ogle, Bennett, Wallace, Müller, Lubbock, Darwin, and others, botany has assumed more of a philosophical character. It is no longer a dry catalogue of names and vegetable virtues. The co-ordination between one great division of the floral world and insects, and between the other and the wind, has elevated botanical study into a higher and more comprehensive domain of philosophy.

It had long been recognized by botanists that, in a loose and generally undefined way, flowers were related both to the wind and to insects. This relation-

ship is now shown to be *exact*, not general. Nowhere in the organic world do we meet with structures more decidedly adapted to definite ends than in flowers. The minute study of the relationship between the shapes and sizes of the different floral organs, their colours, perfumes, &c., and the structures and habits of the different orders of insects which habitually frequent flowers, has breathed fresh life into modern botany. It never attained to the degree of interest it possesses now; and there is thus mapped out botanical and entomological work which will occupy years to come, and a field of investigation is now thrown open in which the humblest observer has a chance of adding new facts to the general fund of human knowledge.

We may regard flowers as separable into two great divisions — viz. those which bear brightly coloured or highly perfumed flowers, and those having inconspicuous, uncoloured, and unperfumed flowers. This division is not bounded by the older classification of monocotyledonous and dicotyledonous, for both have attractive and unattractive inflorescences alike. All coloured and perfumed flowers are frequented by insects, and are termed *entomophilous*— flowers which are green and unattractive are fertilized by the wind, and are called *anemophilous*. Hence, at the outset, we are presented with the primary reasons for coloured and uncoloured flowers. That the former should delight our eyes and administer to our

æsthetic tastes, is not the primary reason for their existence. We have seen that gaily-blossomed flowers existed as far back as the Secondary epoch, ages before man made his appearance, and when as yet the great tide of mammalian life had scarcely begun to flow. That flowers should administer to our love of the beautiful and true, and should have originated some of the most refined and suggestive spiritual thoughts, is not interfered with by the fact that all their beauty of shape, colour, and perfume had originally a utilitarian origin; and was gradually developed because they were advantageous to the plants themselves! The differentiation between the above-mentioned great classes of flowers is found to extend to the minutest organ and its functions. The *shapes* of every part of the flower are in accordance with the widely marked distinction. Even their *periods* of blossoming are not unfrequently affected. Down to the size and shape of the pollen-grains, there is a differentiation in every floral part, which enables a botanist at once to assign each organ to one or other of the two classes.

Let us commence with the unattractive or inconspicuous (*anemophilous*) divisions of flowers. We should first notice the necessity under which all flowers appear to labour of being cross-fertilized; that is to say, it has been proved by actual experiment, that plants raised from seed produced by flowers whose pistils have been fertilized by pollen

Fig. 40.

Barren Brome Grass (*Bromus sterilis*). *a*, spikelet; *b*, flowering glume.

brought from *another* flower, are stronger, usually taller, and bear more flowers and seeds, than plants which were the result of fertilization by pollen from the *same* flower. Thus the crossing affects both the vegetative and reproductive energy of a plant; and in the keen struggle for existence to which wild plants are subjected, this matter of crossing must powerfully influence the possibility of growth. We can hardly conceive the intensity of this battle. Every spring-tide there is taking place on the peaceful hedgebanks of our green lanes, and in the bosoms of our silent woods, a contest more actively fought out than ever was visible on a human battle-field! The ground is densely packed with seeds shed during the previous autumn, or which have been lying dormant and abiding their time perhaps for years back. There is only room for one seed to develop in one place, but there are perhaps a hundred or more candidates for it. The spring sunshine and warmth stimulate them into germination, and now sets in the fierce conflict for survival. It is evident that advantages like those resulting from crossing must be beneficial to seeds possessing them.

Nature has everywhere forbidden the banns of intermarriage! Her decree is rigidly carried out whenever possible, from mosses up to men. There have been conditions in the history of some of the races of mankind where only intermarriage could save the tribe from extinction. Similarly among plants, there are some flowers which have to adopt self-crossing, either

POLYPETALOUS PLANTS.
IRREGULAR.

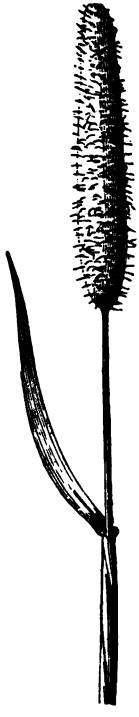
PLATE V.

1. SWEET VIOLET. *Viola odorata.* 2. BROOM. *Sarothamnus scoparius.*

3. SAINFOIN. *Onobrychis sativa.* 4. MONK'S HOOD. *Aconitum napellus. cold.*

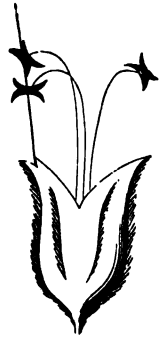
as a rule or as a last resource, and of these we shall have to speak farther on. But the one pre-eminent

Fig. 41.



Marsh Foxtail Grass
(*Alopecurus geniculatus*).

Fig. 42.



Floret of Marsh Foxtail Grass.

Fig. 43.

Slender Foxtail Grass
(*Alopecurus agrestis*).

law in the vegetable kingdom is firmly set against intermarriage, or self-fertilization, even more than in

the animal. All kinds of negative and positive contrivances are resorted to in floral structures to prevent it—all kinds of mechanical and other devices have been evolved in order to induce *crossing*. The shapes

Fig. 44.

Single Floret of Marsh Foxtail Grass.

Fig. 45.

Florets of *Holcus*, divested of their outer glumes.

of the corollas are frequently designed to aid insects in this all-important act, and the very microscopical ornamentations of the pollen-grains are in reality surface roughnesses, intended to make each grain adhere the better to the hairy bodies of bees and butterflies! The filaments on which the *anthers* or "pollen-bags" are suspended, are lengthened or shortened as the case may be, whenever this simple plan is serviceable to crossing. Similarly the *style* of the pistil may be elongated or suppressed, as though at the will of the plant; and we always find that such a modification is advantageous, and designed of set purpose for the benefit of the flower.

Indeed, it is not too much to affirm that the necessity under which flowers exist to be crossed by other pollen than their own, is the key which enables us to understand the marvellous diversities of floral shapes, colours, and perfumes throughout the world! All these attributes of flowers are so many bids for insect services, and their intensity is always proportionate to their need for being crossed by insects. Their different *shapes* are, as a rule, also the result of floral adaptation to different kinds of insects.

The wind-fertilized, or *anemophilous* division of flowers require to be crossed quite as much as their more showy congeners. And, although the devices for bringing about this end are by no means so numerous among the former as among the latter, they are quite as perfect in their special adaptations. This adaptation, also, is continuous throughout the entire reproductive apparatus, from the shape, size, and character of the pollen-grain, to the manner in which the flowers are attached on the plant. As the wind agency is inorganic, and insensible of colour, and perfume, and honeyed nectary, we find that flowers habitually crossed by the wind possess none of these attractions. It would be an act of supererogation on the part of such plants to produce them. But, on the other hand, nothing can be completer, as a means to an end, than the structures of true *anemophilous* flowers. First, we find a microscopical distinction between the shape and appearance of their pollen-grains, and those of the

other division. These grains are lighter, smoother, and often flatter, so as to spread out as much surface as possible, and thus help the wind all the better to carry the pollen-grains by its mechanical force. The distinguishing characters of the pollen-grains of *anemophilous* and *entomophilous* flowers are so constant and peculiar, that the botanist has little difficulty in assigning each to its own division. Then, again, we find the anthers or pollen-bags of wind-fertilized flowers are usually more pendulous than in the other. More pollen is also produced—infinitely more than can be utilized; although the manufacture of this material is exhausting. In this way, the possibility of some of the pollen-grains taking effect is almost certain. So abundant is the pollen developed and shed, that we may frequently see the surface of the ground in pine woods covered with it; whilst the amount shed by the grasses is such as to fill the atmosphere, and produce on sensitive nostrils the annoying complaint of "hay-fever"! The stamens of this wind-fertilized group are either numerous and densely packed, as on the catkins of the poplar, hazel, and birch, or few in number, and suspended on long, dangling, and rapidly growing filaments, as in the grasses and sedges. In the former the stamens may be regarded as a populous colony. Their filaments are short, because the entire catkin is itself suspended and pendulous, so that every breath of wind sets it in motion, and there is no need for the individual sta-

Fig. 46.

Northern Holy-grass (*Hierochloe borealis*). *a*, glumes; *b*, pendulous stamens, and pistil in centre; *c*, pistil, with plumose stigma.

mens to be separately movable. In the grasses, on the other hand, each flower has only three stamens, and each of these has a long filament, enabling the stamen to dangle outside the flower at a different point. Here the easily moved filaments are separately shaken by the wind, and, as the anther or pollen-bag is fastened to the end at its middle part, it follows that the machinery for dispersing the pollen, and enabling the gentlest breeze to loosen and carry it away, is of the most perfect kind. It should be noticed, also, how among the grasses the floral parts are borne on upright stems, often purposely elevated from the otherwise procumbent or creeping condition of the plant, so as to enable the pollen all the better to be caught up by the air. Who that has watched the gentle June breezes sweeping over the surface of a full-grown English meadow, and rippling it into waves like those of the sea, will not perceive how effective such breezes must be to carry off the pollen from the tall flower-spikes? Again, it is part of the floral adaptations of this division of flowers that the catkin-

Fig. 47.

Male Catkin of Willow.

bearing (*amentiferous*) tribes should flower *early* in the year, when our gales are most powerful and persistent, and before the leaves have opened. All our European catkin-bearing shrubs and trees affect this habit, and it will at once be seen that it is most advantageous in the distribution of the light pollen, for the wind can shake the catkins to and fro, and carry away the pollen, without being interrupted by the dense masses of foliage. If the ordinary rule of

Fig. 48.

Single Female Flower of Willow.

Fig. 49.

Single Male Flower of Willow.

the leaves being developed first (which usually exists with the insect-fertilized division) was in force among the catkin-bearers, it would interfere with the free distribution of the pollen by the wind. Nothing could be more advantageously conjoined with the other devices for wind-fertilization than this habit of the flowers appearing before the leaves! Nor, in mentioning the grouping of the mass of stamens into the

male colony we call a "catkin," should we omit to draw attention to the bracts which roof over each pair like an umbrella, and thus keep the wet from

Fig. 50.

Female Catkin of Willow.

spoiling the pollen and interfering with its lightness. The manner in which the pendulous stamens of the grasses dangle outside the flowers renders it nearly impossible for the adjacent pistil to be fertilized with their pollen. In some species this end is absolutely secured by the pistil of the flower ripening before the stamens, so that it can only be crossed by the pollen from another individual. In the nearly allied family of the rushes (*Juncaceæ*) we find a large number of species in which the latter habit is always practised. Such flowers are called *proterogynous*.

In the palms, and such tall species of grass as the

bamboo, the height of the stem whence the flowers emerge must give the pollen a great advantage, in enabling the wind all the more powerfully to carry off the grains as fast as they are ripened.

Next, as regards the structure of pistils of wind-fertilized plants: like the floral organs just referred to, it is perfect after its kind, and well adapted to the work it has to perform. In the grasses and allied orders the pistil is usually forked, each tine of the fork being feathered down to its base. The surfaces of this plumose organ are moist and viscid, and it thus forms an admirable net, capable of catching and retaining any pollen-grain the wind may waft into its meshes. In the hazel the pistil exists apart from the catkins, as a bundle of moist scarlet threads, surrounded by a spiral row of bracts, which protect it until it is ripe enough to protrude. In the birch and other trees the pistils are associated in cylindrical catkins. In the pistils of the common nettle and other wind-fertilized herbaceous plants, the stigmas or tops are usually fringed or otherwise spread out, so as to entangle stray pollen-grains. In the *Coniferæ*, the female flowers are also separate from the male, and are arranged in special cones, in which the small scales bear ovules at their bases. In them, therefore, the pollen-grains are carried direct to the naked ovules, and have not to penetrate overlying and protective tissues by means of their pollen-tubes, as in other flowering plants. In the yew, and other trees of that

Fig. 51.

Pellitory of the Wall (*Parietaria officinalis*). A, pistil with fringed stigma.

division of the *Coniferæ*, the female flowers are large and somewhat showy, having a fleshy disk enclosing the fruit as it matures.

With the exception of the grasses and rushes, many of the wind-fertilized flowers are remarkable for bearing the pistils on one set of flowers, and the stamens on another, but both on the same plant or tree. Such flowers are relatively termed *pistillate*

Fig. 52.

Male Catkins or Flowers of Oak.

and *staminate*. Frequently this separation is carried farther still, so that we have *pistillate* plants and *staminate* plants; that is, some plants bearing only pistils, and others only stamens. It is evident at a

glance that there could not be a simpler or more effectual way of preventing self-fertilization than this. Whilst in the grasses, self-fertilization is prevented by

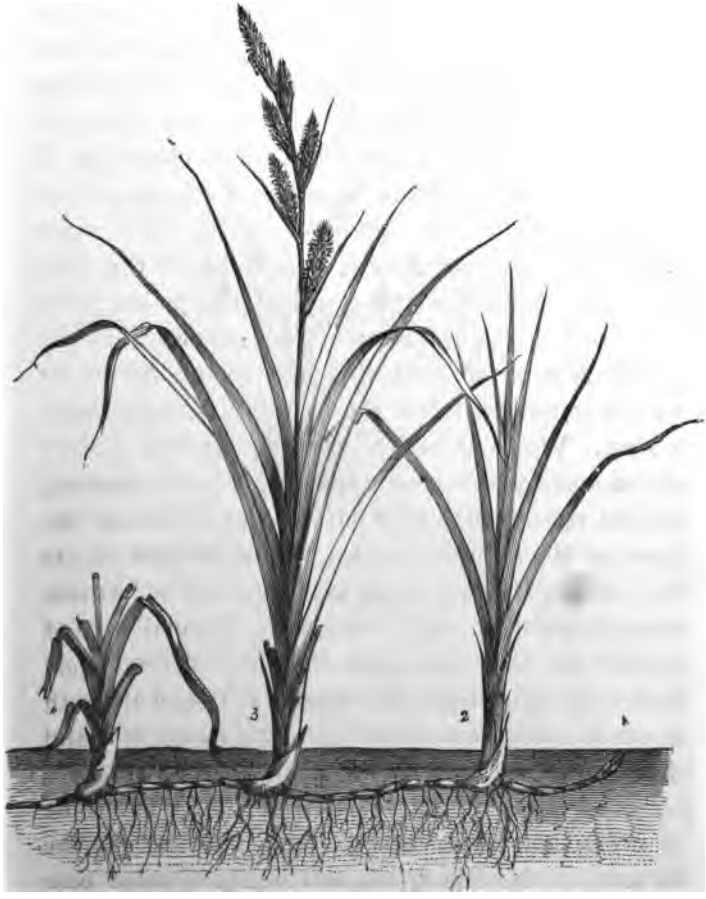
Fig. 53.

Female Flowers of Oak.

the stamens hanging some way outside the flowers, and in the rushes by the pistils ripening before the stamens, in so-called monœcious and dicœcious plants we have the principle put in action of prevention being better than cure. When trees bear male and female flowers on different individuals, crossing must result. In the sedges the flowers are frequently both monœcious and proterogynous. This monœcious and dicœcious condition is not sharply marked off as a habit, for some trees, as the ash, would appear to be now gradually acquiring it. Thus we find in the flowers of the ash (*Fraxinus excelsior*), some bear stamens and pistils according to the usual habit;

others bear stamens and pistils on the same tree. And, again, we have ash trees on which we find

Fig. 54.



Carex, or Sedge, showing underground stem.

pistillate flowers only, or staminate flowers. The common maple (*Acer campestre*) is nearly, but not quite, in the same condition. Here, therefore, we have three different kinds of flowers borne on three individual trees. As if to confirm our idea that the ash is only now acquiring new habits, we may refer to one species of ash (*F. ornus*), which actually possesses a corolla, and is insect-fertilized. The clustering of male and female flowers in separate colonies, or on different plants, and the necessity for such male flowers to hang pendulously, so as to enable the wind readily to shake out and carry off the pollen, have developed a general resemblance among wind-fertilized flowers, so that they are by no means so various in their external shapes as the insect-crossed flowers. We may easily note the pendant flowers of the nettle, dog's mercury, hemp, oak, &c., and the general resemblance they bear to the catkins of the hazel or birch. The *strobiles*, or flower-heads of the hop (*Humulus lupulus*), are externally not unlike the cones of the alder and the *Coniferæ*. No matter what may be the shapes of these wind-crossed flowers, or their mode of growth, their floral habits and arrangements will always be found bearing a direct relationship to the easiest and surest methods of effecting crossing. It is the almost endless variety of means by which this can be brought about that has enriched the world with its gorgeous and highly differentiated flora.

Fig. 55.

Annual Dog's Mercury (*Mercurialis annua*).

CHAPTER VIII.

THE COLOURS OF FLOWERS.

NO conclusion in the study of botany has appeared at first sight so unpoetical as that which declares the *colours* of flowers were originally given to be beneficial to the plants themselves, and not solely for the purpose of occasionally delighting human eyes. Although this inference need not interfere with our enjoyment of the colours of flowers, it seems like an unexpected blow to our self-conceit that we should be obliged to accept this floral beauty at second-hand! To not a few sensitive minds it may appear to clash with the poetical and spiritual associations which have clustered around flowers more than any other organic objects. But, on the other hand, this new knowledge has drawn two life-groups more closely together than we expected. And by so much our conception of the Wisdom with which we associate the evolution and governance of the animal and vegetable kingdoms has been expanded and clarified.

We have already seen that those parts of flowers which are usually the first to strike the eye and fix our attention, the many-coloured and various-shaped petals, are more simply organized than the green leaves, in

spite of the popular notion to the contrary. They have no mouth-organs (*stomata*), veins, or midribs; but, instead, only a comparatively loose cellular tissue. And as gay flowers are usually terminal, or are borne on special stalks proceeding from the axils of leaves or branches, it follows that they are placed where the supply of nutriment must be least. The green colouring matter of leaves is known among botanists by the name of *chlorophyll.* Formerly it was believed to be a simple green pigment, occupying the interior of the cells of leaves. But Mr. Sorby has recently shown that *chlorophyll* is a compound, and is made up of substances which vary in colour from blue to yellow and orange. These substances do not always occur in the *chlorophyll* in the same proportions; hence the variation in the tints of leaves. It is also found that they are differently affected by the action of light, as well as by the supply of nourishment. Hence one cannot wonder at the varying tints of our own autumn leaves, ranging from the bright red of fading cherry and dog-wood leaves, to the equally brilliant yellow of maple and poplar leaves. In North America, towards the close of the "Indian summer," the fading leaves of forest trees and shrubs assume tints more various and beautiful than those which characterize our native woods. Change of colour in a leaf, therefore, is rightly associated with decrease or cessation of nourishment to it. If the nutriment and warmth continued, the leaf would not alter its normal green

hue. But we have seen that the petals of flowers are really *degraded* leaves, situated farthest away from the source of plant nutriment, and therefore likeliest to be soonest tinted. Moreover, we have observed that all the elements of colouring matter are already present in every green leaf, and that all we require to develop them to any colour is to modify the internal structure and physical surroundings of the leaves themselves. In not a few plants the leaves are nearly as brightly coloured as the petals of others. Thus, the leaves of the *Dracæna, Coleus,* and red cabbage sometimes approach to brilliancy. Note, also, how the dwarfed upper and densely-packed leaves of the common purple nettle (*Lamium purpureum*), which lines the bases of our hedgerows in February, are coloured with a mixture of pink and green, which gradually approaches the former at the top, where the pink flowers cluster most numerously. We have already seen that the whorl of bract-like leaves in the *Poinsettia* are of a brilliant scarlet colour, and that the terminal flowers are consequently saved the necessity of developing specially-tinted petals to attract insects, for the row of colour-modified leaves serve the same purpose.

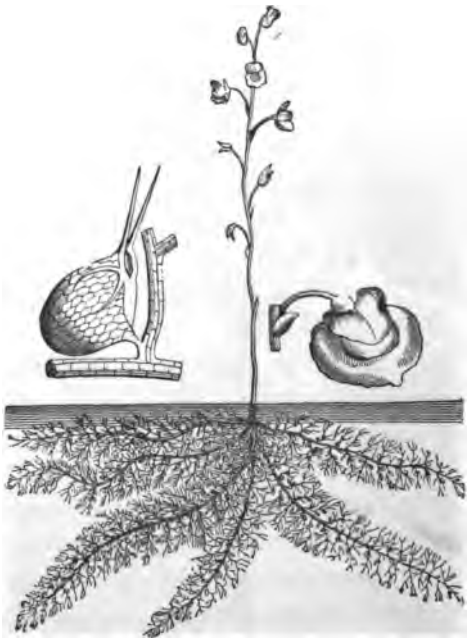
Everywhere in the floral world we meet with the two rules of profuse prodigality and extreme economy, with every degree of difference between the two extremes! It is the moral of the New Testament story—feeding the hungry thousands with a

Fig. 56.

White Dead Nettle (*Lamium album*).

few loaves and fishes, and then "gathering up the fragments that nothing be lost"! What also surprises the thoughtful student of botany is the marvellous manner with which the very shortcomings of plants are turned to special and necessary uses. Here, for instance, are the terminal leaves farthest away

Fig. 57.



Bladderwort (*Utricularia*), showing on left hand one of the "bladders" enlarged; also one of the yellow flowers on the right.

from nutriment, therefore having their internodal spaces shortened. For the same reason they are

small, and liable to have the colouring pigment of their leaves alter. The last-formed leaves are most rudimentary of all. The chances are they will never come to anything beyond the merest rudiments of leaves. Who would dream that out of these materials the most gorgeous flowers could be manipulated? that this very imperfection (if we may call it so) differentiates what would have been actual leaves, if the food supplies had been abundant (as they are, under cultivation), in gardens, into the flowers we love so much and treasure so greatly? And then, to turn away from our own interest in the matter, we have to consider that this poverty of supplies is in reality the means of providing plants with *reproductive*, instead of only vegetative, organs. It requires such a degree of rashness to believe all these important differentiations could be played on so few strings—that results so important can always be ensured with modifications so simple and yet so wonderful—that our bolder-visioned *confrères* must pardon us if we refuse to admit of such designs without a Designer, of such perfect and *constant* adjustments without a superintending Providence! The external envelopes of flowers are those which usually first strike the eye. When we associate the senseless, inorganic agency of the wind with the colourless and perfumeless flowers it habitually crosses, and then compare these with the keen sight and numerous eyes of insects, and the myriad tints and special floral contrivances

of entomophilous flowers, it seems absurd not to allow of manifest *intention* in a differentiation so constantly important and effective.

By actual experiment, Sir John Lubbock and others have demonstrated that insects are attracted by *colours*. But with this fact every cottager in England had long been aware, and had turned his knowledge of it to practical account. The cottager's experiments have further had the disadvantage over those of the indefatigable baronet, inasmuch as they were practised upon a less specialized order of insects than his! The experiments of Sir John Lubbock only involved *Hymenoptera* and *Lepidoptera*, or the bee and the butterfly tribes; the cottager has confined his to the *Diptera*, or house-flies! In the brilliantly-coloured paper "fly-cages" which he has been in the habit of hanging from the roof of his cottage, to save its clean whitewash from soiling, the cottager has practically taken advantage of the attractions which colour has even for the *diptera!* With bees and butterflies, we are well aware, the attraction of colour is even stronger still.

Here, therefore, we have the external whorl of the reproductive organs of insect-crossed flowers, in spite of their simplicity and actually degraded condition, specialized through their very imperfection to act as coloured attractions to insects! The two outside whorls are those of the calyx and the corolla—the sepals and the petals. We shall see how singularly

the office of attracting insects by means of colours is thrown upon one or other of these two different sets of floral organs, as occasion may require. As a rule, however, this duty is performed by the petals of the corolla. But numerous exceptions occur, in which the sepals of the calyx act as deputies, and then we always find a reason for the change of office. Either the petals will be aborted, and found doing duty as *nectaries*, or the position of the flower will be an abnormal one.

Let us take the attractive species of the monocotyledons first. Here we have a highly specialized class, which in reality belongs to a division remarkable for being chiefly wind-fertilized (*anemophilous*). But a differentiation had probably taken place before exogenous or dicotyledonous plants had been evolved to any degree. The *iris* and *lily* families are among the oldest of flowering plants. Leaves like those of the yam have been met with in early Tertiary strata, and they may be even of Cretaceous age. In the above orders we have some of the loveliest in colour and perfume of known flowers. Around many of them the most poetic of mythological and sacred traditions have clustered. Their geographical distribution is extensive, indicating a geological antiquity; so that their beauty has become the common property of mankind. These lilies of all kinds are remarkable for being insect-fertilized. A large number of the species are *white*, so that they are plainly

visible at night, when evening insects, such as moths, are out; and then it is that their perfumes most powerfully load the moist evening air. Indeed, we find that *white* flowers have the greatest average of sweet-smelling ones. Either the flowers are large,

Fig. 58.

Speedwell (*Veronica officinalis*).

and then they are single or few in number, as in *Lilium auratum*, or they are numerous and small, as in the well-known lily of the valley (*Convallaria majalis*) and Solomon's seal (*Polygonatum multiflorum*). Number and size are nearly always related

to each other in the grouping of flowers on any plant. When any of the lilies are less conspicuously white or coloured than usual, as is the case with the lily of the valley, which is greenish white, then we shall find this defect more than compensated by an overwhelming sweetness of perfume; and, as the lily of the valley is visited by night insects, its odour cannot fail to attract them. The day-loving lilies are distinguished from the night-loving by their brilliancy of colour. Usually one or other of the primary colours is employed to paint them. For instance, we have a splendid yellow in the wild tulip (*Tulipa sylvestris*) and yellow gagea (*Gagea lutea*), an equally attractive blue in the hyacinth (*Hyacinthus non scriptus*), grape hyacinth (*Muscari racemosum*)—so abundant as a weed in the vineyards of France—and in our own two species of squills (*Scilla*). In the martagon lily (*Lilium martagon*) the colour is a peculiar red. In the fritillary we have a chess-board pattern of purple and brown, so singular in its effects that the flowers cannot fail to arrest the attention of insects. The sub-tropical and warm-temperate species of lily, as the yuccas, asphodels, aloes, &c., are even more markedly attractive, in size, colour, and perfume, than our British species.

If we examine any of these flowers we are surprised by what appears to be the *absence* of a calyx. A closer examination, however, will show that the calyx is present, but its three divisions are coloured or

marked exactly like the three divisions of the corolla, so that the flower is composed of six petal-like pieces. Whenever it occurs that the calyx is coloured and patterned like the corolla, the combination is termed a *perianth*. It will be seen how effectively the few petals (never more than three in number) of the lilies, irises, &c., are aided by the sepals assuming petaloid characters, so that the combination produces the loveliest coloured flowers in the world. In the nearly allied order *Irideæ* we have some well-known British and exotic flowers, equally remarkable with the lilies for the primary colours which adorn them, such as the common yellow iris (*Iris pseudacorus*), the blue or German iris (*Iris germanica*), the crocuses, blue and yellow, the brilliant scarlet *Gladiolus*, &c. In the iris we find the calyx and corolla leaves coloured in nearly the same degree. To intensify the effect, the former are usually bent backwards. Within the flower the stigmas are actually flattened out into arched, petal-like leaves, delicately coloured, which conceal and protect the stamens. In such well-known orders as *Alismaceæ* and *Hydrocharideæ* we have the water plantain (*Alisma plantago*), flowering rush (*Butomus umbellatus*), arrow-head (*Sagittaria sagittifolia*), frog-bit (*Hydrocharis morsus-ranæ*), all of them affecting aquatic habits, and each distinguished for the delicate tints of its flowers. The latter, however, is only a coloured *perianth*, made up by the sepals of the calyx aiding the petals of the corolla, by being

modified from the usual green colour, which is the common heritage of calyces, so as to resemble the petals

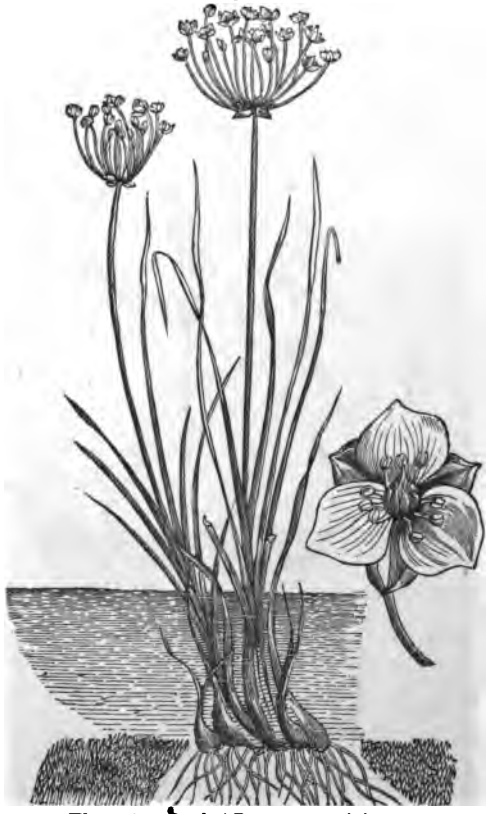
Fig. 59.

Water Plantain (*Alisma plantago*).

themselves. In the *Amaryllidæ* we have a widely scattered group of plants, equally remarkable for

owing their brilliancy of colouring to the same device. Among our British species we have some which are

Fig. 60.



Flowering Rush (*Butomus umbellatus*).

white, and therefore which open most widely in the evening, when their perfume is also most powerfully

diffused. Night-flowering plants may usually be distinguished by the clear white flowers they bear,

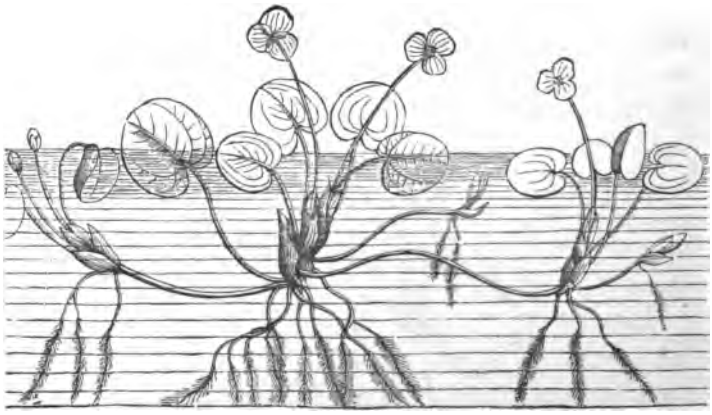
Fig. 61.

Arrow-head (*Sagittaria sagittifolia*).

and, although such flowers may open by day as well, it does not follow that their *whiteness* is not a direct

adaptation to the moths and other night-flying insects, on whom *colour* would be lost in the darkness, and to whom only white or light-coloured flowers (such as

Fig. 62.



Frog-bit (*Hydrocharis morsus-ranæ*).

those of the evening primrose) would be visible to the eyes. If we could take a census of British wild flowers, we should probably find that the most numerous colours are in proportion to their *luminosity*, or the ease with which they can be seen from the greatest distance.

There are about twenty-five times more species of British moths than butterflies, and they are of all sizes, so that in this respect they suit all magnitudes of white flowers. None of them possess any other mouth-apparatus than a sucking-tube, used for being thrust down the corollas of open flowers in

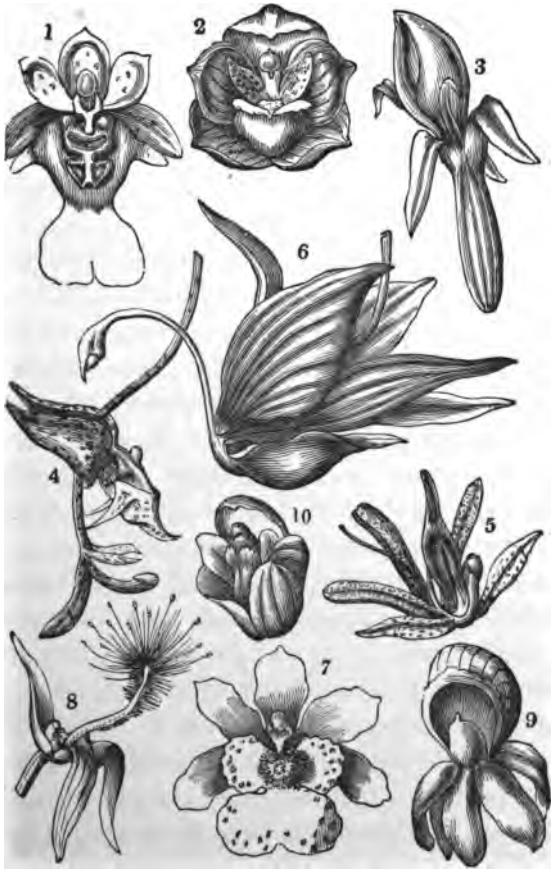
order to reach and tap the honeyed nectaries at their bases. The extraordinary number of species of moths, and the general abundance of individuals, prove that there must be floral night supply equal to their demands, for, with the exception of the clear-wing moths (*Sesia*), the Burnet-moths, and the rarer humming-bird moth, we seldom see this group visiting flowers during the day-time. Many common plants bear *white* varieties of flowers, such as the milkwort, the hyacinth, self-heal, heath, and a host of others, and this apparently abnormal defect of colour may in reality be of service to such flowers by causing them to be visited during the night by moths.

Among the *Amaryllidæ* we have the poet's narcissus (*Narcissus poeticus*) — one of the most exquisitely perfumed of all our flowering plants. In this respect it is not outrivalled by its near ally, the jonquil (*Narcissus jonquilla*), whose brilliant yellow perianth proclaims it a day and perhaps also a late evening flower—yellow being visible longer than any other colour. The delicate snowdrop (*Galanthus nivalis*), with its drooping greenish white head, cannot fail to be seen when flowers are so few. There can be little doubt it is visited by moths during the latter part of the day, for there are few butterflies abroad (except on sunny days) when the snowdrop appears; whereas winter has its regular brood of moths. The daffodils, coming "before the swallow dares," and taking "the winds of March with beauty," by their brilliant

yellow colour, are visible to insects in the early spring evenings much longer than they would be if they had been red or blue. Both them and the jonquils are remarkable for having a "corona" or tube within the flower, which, in addition to the aid afforded by the sepals being coloured like the petals, is an extra adjunct assisting in giving the flower its extraordinary attractiveness.

The *perianth* may not be always composed of a number of loose pieces, although it is made up, as we have seen, of the sepals of the calyx and the petals of the corolla. In flowers of extraordinary high specialization—that is, those which have undergone most structural changes—such as we have already seen is the case with the *Orchidaceæ*, these parts may be often fused together. Then we have a flower in one piece. That piece may be of an irregular and multifid shape, as it usually is with the orchids. Among such plants as the *Labiatæ* we have only the petals of the corolla grown into one piece; and here also that piece is irregularly shaped, as anyone may see in the common red or white dead nettle. The difference between an irregular flower of the orchis and one of the dead nettles is that the former is a true perianth, formed of the partly amalgamated divisions of calyx and corolla; whereas the latter is a true corolla, its green calyx still supporting it. And yet nothing can exceed the variety of tint and colouring visible in the orchids, whether British or exotic.

Fig. 63.



Various shapes of Orchidaceous Flowers:—1. *Oncidium raniferum*; 2. *Peristeria elata*; 3. *Prescottia colorans*; 4. *Gongora fulva*; 5. *Cirrhæa tristis*; 6. *Cycnoches ventricosum*; 7. *Oncidium pulvinatum*; 8. *Bolbophyllum barbigerum*; 9. *Catasetum viride*; 10. *Peristeria cerina*.

A coloured calyx, coming to the aid of the corolla, is not limited to the monocotyledons, although it is peculiar to all the attractive flowers of the latter. It is frequently met with in orders of dicotyledonous plants, and its employment is not peculiar to any one specially—a fact which indicates that in these scattered instances the colour must have been acquired. In the marsh marigold (*Caltha palustris*) — the "Mary-Buds" of Shakspeare — we have the sepals of the glossy and brilliant yellow colour which usually distinguishes buttercups. Here the true petals of the corolla are shrunk and aborted, or rather utilized as nectaries. In the meadow rue (*Thalictrum flavum*) the flowers are nearly in the condition to which children reduce buttercups when they have plucked off the petals, and left only the numerous yellow stamens clustering around the minute and sessile pistils. But in the meadow rues the stamens are longer, and their anthers brighter coloured, so that they form a floral tassel as attractive as the yellow male catkins of the willow. In this way a little floral economy has done away with the necessity of the usual attractive floral envelopes! Whenever the true petals of dicotyledonous plants are aborted, or converted to other purposes than that to which they are usually assigned, we generally find the calyx doing duty for the corolla by being brightly or attractively coloured. This is the case in the larkspur (*Delphinium*), the monkshood (*Aconitum*), columbine (*Aquilegia*), &c. Many of the

Fig. 64.

Columbine (*Aquilegia vulgaris*).

sepals of the calyx in the common buttercups are slightly coloured yellow; hence the character of "petaloid" applied to them. In the *Anemones* and *Hepaticas* also we frequently find that not only are the calyx divisions or sepals coloured, but the petals are aborted or absent.

Not unfrequently we see the green sepals of the calyx, after having acted as nurses and protectors to the petals of the flower-buds, falling off immediately after the flowers open, as if they were anxious not to interfere with the success of the floral functions. This is the case with the sepals of many of the buttercups, notably of the common *Ranunculus bulbosus*, of most if not all the poppies, of the peony, the bright yellow *Escholtzia* of our gardens, &c. Or we find that, if the flowers assume a drooping character, as in the various species of heath and the harebell (*Campanula rotundifolia*), the calyx divisions will be reduced to a minimum in size, and the sepals be found scarcely bigger than threads. Had the calyx been large in size, then the drooping position of the flower would have made the calyx more visible than the corolla, and thus the colouring effect of the latter would in a great measure have been lost. But when its size is thus reduced, it is evident that the fullest effect is given to the attractions of the pendant flower. Or, instead of in the least degree interfering with the colour of drooping flowers, when the corolla is required to be large, the difficulty is got

Fig. 65.[1]

Bilberry (*Vaccinium myrtillus*).

over by having the calyx *coloured* as well, thus aiding instead of interfering with the floral attractiveness. Such is the case with the flowers of the berberry, where we see the outside whorl of petaloid sepals even more strikingly yellow than the inner petals, the sepals being most visible. This modification of the otherwise generally green colour of the calyx is still more evident in the flowers of the *Fuchsia*, where it is of a bright red colour, and more than half encloses the flower. In the equally pendant flowers of that common garden plant, *Dielytra spectabilis*, the two sepals are of a brilliant pink; and in reality the beauty of the flower is mainly indebted to them. In the yellow *Corydalis*, the common fumitory, the various species

Fig. 66.

Flower of Indian Cress (*Tropæolum majus*), showing keel.

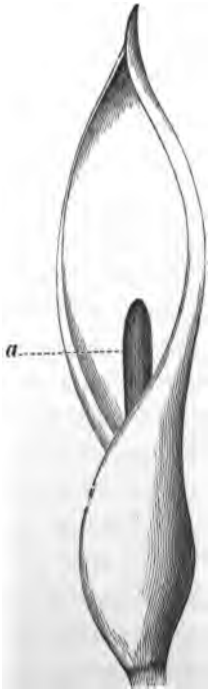
of *Tropæolum* we have coloured calyces assisting in the floral attractions of the entire flower. In the Cape

species of *Polygala*, grown in our greenhouses, the sepals are remarkable for their vivid colouring. We need not multiply instances of this kind, but simply point out the fact that a *coloured* calyx is generally present when the flower assumes a drooping position, and when the usual greenness would have interfered with the end for which the petals of flowers are tinted.

The contrivances, among various species of plants, for producing the greatest effect with the most economical resources of colour are almost endless. We have already referred to the modification of the terminal bract-like leaves in the *Poinsettia*, and their assumption of a brilliant scarlet colour, so that no petals are needed, the coloured bracts doing duty instead. In the *Bougainvilleas* there exists a similar contrivance, the true flowers being concealed by triplets of the most lovely coloured leafy bracts, the whole forming a magnificent inflorescence. In our common cuckoo-pint, or "lords and ladies" (*Arum maculatum*), we have a species representing one of the oldest orders of flowers in the world; that is, supposing Mr. Carruthers' opinion is correct that the fossil flowering plant found in the Coal measures really belongs to the *Aroideæ*. In the *Arum* we have the green spathe, swathing an upright *spadix*, on which are arranged separately groups of stamens and pistils, with rows of others which have become barren. The upper part of the spadix is seen boldly projecting

above the heart of the spathe, and its bright purple tints show all the more plainly because of the glossy background of green. This coloured organ is quite

Fig. 67.



Cuckoo-pint (*Arum maculatum*). *a*, spadix.

Fig. 68.

Spadix of *Arum maculatum*, showing *b*, fertile pistils; *c*, aborted ditto; *d*, fertile stamens.

sufficient to attract small insects, which become imprisoned within the spathe, the hairs within which

allow of ingress to the interior, but not of egress until the pollen has been shed on them, and they are sufficiently dusted with it to carry some away, and thus cross other individuals. In the well-known "trumpet lily," or white arum (*Richardia*), to be seen in most cottage windows, we have the investing spathe of a perfect white, and altogether simulating a corolla. Its effect is heightened by the brilliant yellow colour of the spadix which peeps from within. In the composite flowers of the *Helichrysum*, one of the most abundant of South African genera in the "bush," the scales of the involucre on which the florets are arranged are not only highly coloured, but generally of the same tint as the rays. And as these scales are *scarious*, or dry, they do not fade, but convert the flowers into the condition popularly termed "everlasting." We have the same principle in force in an Australian genus of *Helichrysum*, and we find it equally effective in the flowers called by the French "immortelles." It is evident that an extra aid of this kind, called in to assist the true floral organs in attracting insects, must be especially advantageous in such arid regions as the "bush" of the Cape, where we find assembled the most beautiful flowers in the world, so that the struggle for life must be there very keenly fought out, and the bidding for insect services carried higher than elsewhere!

In noticing the colours of the petals of flowers we find certain laws in operation which indicate special

Fig. 69.

Grass of Parnassus (*Parnassia palustris*), showing veined petals.

adaptations of means to ends. This is the case with the coloured and converging lines or *veins* which mark the petals of mallow, wallflower, geranium, pelargoniums, and hosts of other smaller flowers. They have been alluded to by many poets, but their uses have been only recently discovered. In Sir John Lubbock's charming work on the 'Relation of British Wild Flowers to Insects,' we find the idea adopted that they serve as *honey-guides* to insects. They invariably converge towards the nectaries at the bases of the petals and stamens, and an insect following them would be surely led to where the honey was secreted. But this service is not purely gratuitous on the part of the plant. The insect, in following the streaks or veins to the honey stores, is sure to have its body dusted with pollen, or to bring its already powdered body into contact with a pistil ready to be crossed. It will therefore be seen that the coloured veins or petals are advantageous to flowers possessing them. As might be expected (if this explanation be the true one) night-opening flowers never possess *veins*, for they would not be visible to moths in the dark!

The remarkable manner in which the flower "is made the most of" (to adopt a common expression) in some species, cannot fail to arrest attention. Thus, in the common *Cyclamen* of our gardens we have the petals bent completely backwards, so as entirely to cover the calyx, and this contrivance brings every

part of the surfaces of the petals into conspicuous notice. In the *Dodecatheon*, or American cowslip, we find the corolla deeply cleft, and each petal bent backwards, as in the cyclamen, and for the same purpose. Plants like these seem to be putting forth all their efforts into the floral competition for insect services. In such arrangements of flowers upon their stalks as we see in the forget-me-not (*Myosotis palustris*), whereby the clusters are coiled up in a crozier-shape, like the fronds of unopened ferns, we have another method for arresting ocular attention. The flowers here have various colours or tints according to their stage of development—at first *pink*, afterwards blue. One species (*Myosotis diversicolor*) bears red, yellow, and blue flowers respectively. In the viper's bugloss (*Echium vulgare*) and others of the order *Boraginaceæ*, we find the inflorescence most attractive, on account of the combination of the rose-colour and bright blue of the unopened

Fig. 70.

Forget-me-not (*Myosotis palustris*).

and opened flowers. There can be no question that this utilization of the different colours of the buds

Fig. 71.

Scorpioid inflorescence of Comfrey (*Symphytum officinale*).

and flowers, especially when both are closely packed together, as we find them in this scorpioid mode of

inflorescence, must be advantageous to them in attracting the attention of insects.

A few flowers have the power of changing the colours of their petals, either during their brief life-time, or during the short space of each day they remain open. The flowers of the common hawthorn habitually pass from pure white to a reddish tint just before they fall off. In the red varieties of the hawthorn this latter habit may have been modified and intensified so as to produce the change in colour. One of the most notable changes of colour, during each day, is visible in the petals of the *Hibiscus mutabilis*, not uncommon in our gardens. We see them *white* in the morning, *rose-coloured* during the middle of the day, and *red* in the evening. These changes are repeated day after day, as long as the flower lasts. *Gladiolus versicolor* similarly changes from brown in the morning to blue towards evening. If variety be effectual in administering to the curious appetites of insects, such plants as these must be gifted above their fellows. Not unlike this habit is that of some species of producing individual flowers differently coloured, or varieties distinguished by their difference of colour alone, as in the white, pink, and blue milkworts (*Polygala vulgaris*). The field pimpernel (*Anagallis arvensis*) has both red and blue flowers; whilst the peculiar *Anemone patens* of Siberia bears white, yellow, and red flowers. Here there is some tendency to division of labour, or rather it is

like a man fishing with different kinds of bait, in order that if the fish won't bite at one they may be induced to do so at another! We have already suggested that "white varieties" in flowering plants may often be minute modifications of flowers with a view to availing themselves of night-flying insects, to whom *white* would be visible better than colours; so that such flowers would have an additional chance of cross-fertilization over their coloured brethren.

The *distribution* of colour over the various parts of flowers is not accidental. We commonly find that when all the petals are equal in size and shape, all are equally coloured or streaked. But as soon as one petal is enlarged for any special purpose in the economy of the plant, although the enlargement may be comparatively trifling in degree, a change in colour or adornment immediately ensues. This is seen in the petals of the violet, pelargonium, and many others. But when the change in shape is carried to a high degree, as it is in the petals of all papilionaceous flowers, such as those of the pea, bean, &c., then the part which is the largest is either of a different colour (as we may see in the sweet pea), or it is differently marked. When the petals of a flower have grown together so that a *gamopetalous* corolla is the result, then, if this be of an irregular shape,

Fig. 72.

Violet.

as in the flowers of the weasel-snouts (*Galeobdolon*), the blue *Salvia*, snapdragon, and others, there is not so much difference in the colours of the united parts, except the lower, which are usually spotted, or more brilliant in colour. So singular is the specialization of shape and colour in many instances that a botanist could predicate the effects upon one from a knowledge of the conditions of the other.

Even the method of inflorescence bears a relation to insect-crossing. Something like the mechanical principle that what is lost in power is gained in time, and *vice versâ*, seems to be in vogue in such kinds of inflorescence as that of the spike in the vervain, or the coiled-up (*scorpioid*) flower-buds of the viper's bugloss, and forget-me-not. Here we have the flowers opening in turn, one after the other, so that such plants frequently remain in flower the entire summer. This must give the plants a better chance of having some, if not all, of their flowers fully crossed and fertilized. On the other hand, in umbelliferous flowers, and those bearing flowers arranged in cymes and corymbs, as the common sweet-william (*Dianthus barbatus*), the flowers are usually shorter lived, but they compensate for this by the effect of their greater attractions of colour and mass, which they put forth in the shorter time.

In this brief outline we have seen how the various colours of flowers may be the result of different modifications of the parts of the plant, although the *petals*

1. VIPER'S BUGLOSS. *Echium vulgare.* 2. SNAPDRAGON. *Antirrhinum majus.*
3. BETONY. *Betonica officinalis.* 4. FOXGLOVE. *Digitalis purpurea.*

Fig. 73.

Tamarisk (*Tamarix gallica*).

Fig. 74.

Spike of Flowers of Vervain (*Verbena officinalis*).

are those which are normally coloured. Further, we have endeavoured to show that the intensity and modification of all the colours of flowers (however the latter may be produced) have been acquired in proportion as the flowers needed insects to cross them. This interdependence of two groups of organic objects, insects and flowers, has increased during each succeeding geological period since they first appeared; and the result of their mutual reaction has been to clothe our meadows, moors, fields, and forests with robes of changing yet everlasting beauty.

CHAPTER IX.

THE EXTERNAL SHAPES OF FLOWERS.

THE shapes of flowers bear scarcely less relation to the visits of insects than their colours; whilst in numerous instances they are directly adapted to favour easy access to the inner parts of the flowers. When we remember the origin of the sepals and petals—that they are modified leaves, suppressed of their internodes and arranged in whorls—we see that the largest number of flowers have been altered from this original modification as little as possible, consistently with the requirements of the plants. The commonest and simplest type of flower, therefore, is

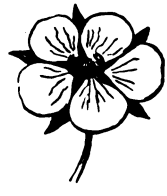
Fig. 75.

Flower of Foxglove.

Fig. 76.

Open Flower of Wild Rose.

Fig. 77.



Expanded Flower of Strawberry.

that of a polypetalous corolla, such as we see in the buttercups, poppies, roses, &c. In these the petals are

arranged in such a manner that there is ample room and verge enough for the numerous stamens and pistils, and for insects to gain ready access to them. Such corollas are opened to all classes of flower-haunting insects alike, and their shapes are not specialized so as to admit only a few, as is the case with the foxglove and some orchids. Their colours are usually most vivid on the *inside* of the petals, that being the surface most visible when the flowers are expanded, as in the buttercups, where they are brilliantly yellow and glossy, and the roses, where only the inner surfaces are streaked and tinted. This generalized shape is not affected by size. It comprehends flowers from the *Victoria regia* to the water crowfoot. When the stamens are few in number, and there is consequently less need to have the petals arranged loosely, so as to allow of the presence in the middle of bunches of them, the petals are frequently clawed, and their claws bent at nearly right angles to the surface of the flower. This causes the throat of the flower to be narrow, as in the various species of *Cruciferæ*—wallflower, arabis, Virginian stock, &c. In the pinks and carnations the claws of the petals are of unusual length, and have to be supported by a calyx in which all the divisions are united. Such a plan produces throats in flowers, and then only certain insects can reach the nectar or honey (which is usually at the bottom), as have sucking mouths or probosces, like the butterflies and moths. As a rule, the entrance to

the throats of such flowers is differently tinted or coloured to the rest of the petals, although this is more specially the case in deep-throated gamopetalous flowers.

The division between flowers whose petals are separated (*polypetalous*) and those in which they are united into one piece (*gamopetalous*), although tolerably well marked now, must have once been much less decisive. There can be little doubt that the reason why gamopetalous flowers appear later in geological time than polypetalous is because they were transformed from the latter condition. The process was simple enough, and probably was brought about by the margins of the petals growing together. Not un-

Fig. 78.

Flower of Carnation.

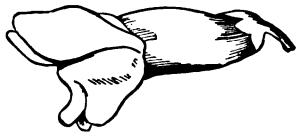
Fig. 79.

Gamopetalous Corolla of *Convolvulus.*

frequently, in "monstrosities," we have illustrations of how this can be effected. Thus, one of the common

"monstrosities" of the poppy is for its petals to grow together into the shape of the flowers of the convolvulus. Similarly we have in other freaks evident returns to ancestral conditions of the flower, as in the common harebell (*Campanula rotundifolia*), when we get specimens with the bell split up into separate pieces or petals. Thus the *normal* condition of polypetalous plants is the "monstrous" state of the gamopetalous, and *vice versâ*. Among papilionaceous flowers we often find the two lower petals growing together along their edges, so as to form the piece called the "keel." Again, the degree of difference between gamopetalous and polypetalous flowers varies considerably. Sometimes the petals only just cohere, as in the flowers of the speedwells and pimpernels; at others we find them well grown and fused, as in the *Labiatæ*. But the latter are known to be among the latest developed of flowering plants, so that this extreme cohesion has been brought about in course of

Fig. 80.



Personate Flower of Snapdragon.

Fig. 81.

Bilabiate Flower of Sage.

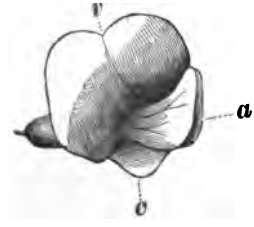
time. In the *Scrophulariaceæ* we have similar evidence of strong cohesion of floral organs, although it varies considerably in such flowers as those of the veronica, figwort, snapdragon, and foxglove.

Very similar changes to these are rung upon the calyx, whose relation to the corolla is like that of contralto to soprano in music. Its parts are more frequently joined, perhaps, than those of the corolla; and there are numerous instances in which they cohere into a long tube, as in the pinks. Sometimes, however, the sepals or calyx divisions are not united when the parts of the corolla are, as in the convolvulus and heaths. At other times the sepals only just cohere—the slightest monstrosity, produced by an arrest of nutriment, might in such case convert them from the gamosepalous to the polysepalous condition.

Fig. 82.

Flower of St. John's Wort.

Fig. 83.

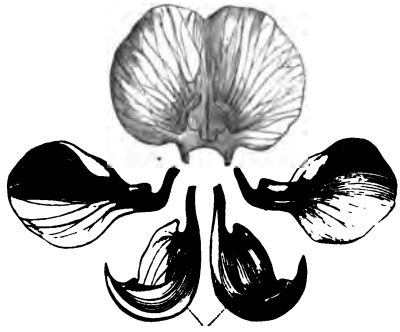


Flower of Pea. *a*, side petals, or *alæ*; *c*, keel; *v*, standard.

In unequally shaped flowers, such as those of the pea in one group, and of orchids in the other, we find the petals to some degree intended to do dif-

ferent kinds of work. In the pea family the large upper external petal is usually brightly and attractively coloured, so as to justify its botanical name of the *standard*, for it cannot fail to attract insects when expanded. The lower petals, on the other hand, are frequently joined together, and form one piece. Within this lie the stamens and pistils; it also forms the "doorstep" to the entire flower (if we may be pardoned a common expression), on which insects can alight. On their attempting to enter the throat of

Fig. 84.



Flower of Pea dissected, to show relative sizes and shapes of petals.

the flower, by springing open the side petals (*alæ*), the stamens beneath are liberated, and are dashed with some force against the insect's body, so as to cover it with pollen. In the *labiate* order of flowers—an extremely large and widely distributed group—we have the petals all joined to form one piece. This piece, although in reality formed of *five* parts, has three of

them developed more than the other two, which exist on each side the opening to the flower as small indentations. The upper part, or hood, bends over and shelters both stamen and pistil, whilst the two lower enlarged and conjoined petals form the "lip," or doorstep, on which insects easily alight. It is frequently more highly coloured or spotted, so as to be as attractive as possible. On these lower lips insects can readily alight, and in all *labiate* flowers we may observe how they are grouped on the stalk so as to give this lip the utmost prominence, and render it as convenient for insects to step upon it as possible.

Although the orchids are far removed from the *Labiatæ*, and their coloured parts are formed by quite different organs, we find much of the same general plan entering into their construction. There is the "labellum," or doorstep, always gayer and more attractive in colour and ornamentation than the rest of the flower, on which insects can alight; whilst the upper parts shelter the *pollinia* (which answer to stamens), just as we have seen the "hood" does in the flowers of the blue sage and other labiates. And no matter how the orchids may grow, whether on the ground or epiphytally on trees or rocks, we always find the flowers so arranged and turned as to bring this "labellum" into necessary prominence. In the *Scrophulariaceæ* we may observe a similar arrangement for the accommodation of insects resting, in the prolongation and slight up-

Fig. 85.

Self-Heal (*Prunella vulgaris*), a common labiate plant.

tilting of the lower part of the flowers of the common foxglove. In the personate flowers of the snapdragons the lower part is double-lipped, whilst in that of the lousewort (*Pedicularis*) it is both gaping and double-lipped, and in external form comes very near to the pattern on which labiate flowers are constructed. In the *Calceolaria* of our gardens we find the corolla modified in this respect to its utmost, more than three-fourths of it being used in the richly coloured and highly ornamented lower part, on which it is so easy for insects to alight and rest, or proceed to explore the nectarine stores within the throat. In the corollas of the musk and monkey flowers (*Mimulus*) the modification of the five conjoined petals is not so great; but even here it may be noticed how the lower parts are more fully developed, and slightly curl upwards, so as to offer alighting accommodation.

Fig. 86.

Flower of *Calceolaria.*

Mr. Herbert Spencer has shown that flowers which are arranged on the *summits* of upright stalks, as in the buttercup, and a host of other well-known plants, are always marked by what he calls "radial symmetry;" that is, their petals are always equal in size and colouring. On the other hand, flowers which are arranged along the sides of stalks in a sessile or stemless manner, are usually *bilateral.* Transitions commonly occur between the two types; but Mr. Spencer is of opinion that in any case the bilateral

has been derived from the radial. The latter, he thinks, is the most primitive type of flora, and resulted from the suppression of the internodal spaces between the modified leaves, as we have already seen. In the flowers of various species of *Begonia* there is a capital series of intermediary forms between the radial and the bilateral, commencing with *Begonia rigida* and ending with *Begonia jatrophæfolia.* In the beautiful and attractively coloured *Gloxineas* of our conservatories we have one well-known species, viz. *Gloxinea erecta,* which is an upright and terminal flower, and therefore *radial.* Its five parts are all uniform and symmetrical. Among the willow herbs there may be observed a similar tendency to variety in the petals, according to the position of the flower. But in the ordinary species, in which the tube of the flower is inclined at an angle on the stem, the petals are unequal in size and shape, the lower part of the flower protrudes as it does in *Mimulus,* and thus forms an alighting stage for insects; in other words, these flowers have become bilateral instead of radial, because their different position on the stem makes that the most advantageous shape. An inclined attitude on the part of a flower, therefore, usually results in the modification of a symmetrical and radial shape into a bilateral or two-sided one. This is usually effected by the partial suppression of the side petals, or the enlargement of the upper and lower ones.

Dr. Darwin has shown how wonderfully the shapes

Fig. 87.

Tree Mallow (*Lavatera arborea*).

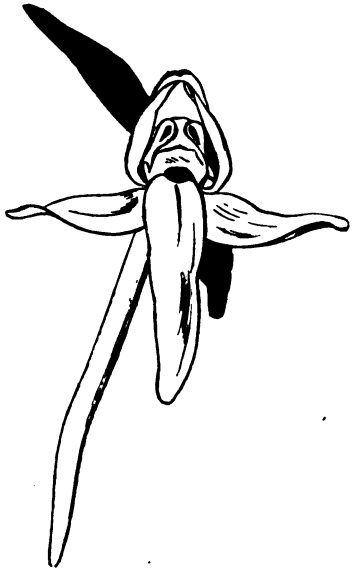
of the flowers of nearly all orchids, English and exotic, are adapted to the visitations of different kinds of insects; and we refer our readers to his work on 'The Various Contrivances by which Orchids are Fertilized by Insects,' as one of the most delightsome of botanical books. Perhaps no other groups of flowers have been so specially modified in floral parts, although the structure of the flower is in reality less complex than in ordinary flowers. Every part of the flower of an orchid seems purposely shaped and adapted to do some special work in its economy. The upper portion protects the delicate pollen-masses, the hinder part is prolonged into a tube or nectary, which, however, does not yield nectar until it is gnawed, and the lower divisions of the flower are at once a tempting and convenient alighting stage for insects. Even the pollen-masses are specialized in a marvellous degree, and are usually associated with mechanic contrivances intended for adherence to the probosces and bodies of butterflies or moths. The perfumes of orchids are as various as their shapes, and even their honey seems to have a variety of flavour which makes it relatively more sought for by some insects than others. And yet, among the orchids, there are not wanting some species which appear to be self-fertilized, as the bee orchis and the fly-orchids. The former has nevertheless a most attractive appearance; it is one of the most remarkable among the mimicking orchids; some botanists having even ex-

Fig. 88.

Ladies' Tresses Orchid (*Spiranthes autumnalis*).

pressed it as their opinion that its striking resemblance to a bee is for the purpose of driving away those insects! That it is habitually self-fertilized every botanist knows; but there are some singular facts connected with its life-history which have not yet been made out. It would appear as if it had special seasons for flowering, and others for growing and not flower-

Fig. 89.



Flower of Butterfly Orchis (*Habenaria chlorantha*).

ing—a kind of imitation of the "alternation of generation" so frequently seen among the lower animals. It may be that these orchids are *occasionally* crossed,

once in a few generations, and that such an occasional cross is sufficient; something after the manner in which the plant-lice (*aphides*) breed. In these insects we find that one pairing of the male and female is enough for seven or more generations, when sexual service is again required. The intermediate generations are born without sexual intercourse—hence the

Fig. 90.

Side view of Butterfly Orchis.

name of *parthenogenesis* applied to this mode of reproduction. Nor is this the only matter in which some orchids imitate the habits of animals. Three

supposed *genera* of exotic orchids, each with a specific name, have been required to include the vagaries of one species. Thus *Monocanthus viridis*, *Myanthes barbatus*, and *Catasetum tridentatum* are now known to be only *one* species. The first includes the flowers of the *male;* the second is possibly neuter, for it sometimes appears on the same stalk of flowers as the males; whilst the last-named species is in reality the female only of the first! All these flowers have actually been found growing on the same plant. Such a circumstance reminds us of a similar mistake made by naturalists with that not uncommon fish off our southern shores, the Wrasse. Male and female are differently coloured and marked, and have been named as distinct species; whilst the young have actually been set down for a *third* species distinct from the other two! Such kinds of orchids as the last mentioned may therefore be called *polymorphic*. It is a character formerly deemed peculiar to animals; but recent investigation proves it is extensive among flowers. Thus, we have a large list of common flowers, such as the violet and wood-sorrel, which bear a second set of flowers other than those with which everybody is acquainted. These flowers are inconspicuous, and are borne on short stalks near the roots. They never open their aborted parts, have no colour, perfume, or honey; and resemble the very young flower-buds of the ordinary violets and wood-sorrels. In many instances there are more seeds produced by

this second and hitherto unknown set of uncoloured flowers than by the showy ones! In one species of wood-sorrel (*Oxalis incarnata*) from the Cape of

Fig. 91.

Wood Sorrel (*Anemone nemoralis*) with "monstrous" petal formed instead of true leaf.

Good Hope, the ordinary flowers are trimorphic as to the lengths of reproductive organs, and the same plant bears a crop of closed (*cleistogamic*) flowers as well.

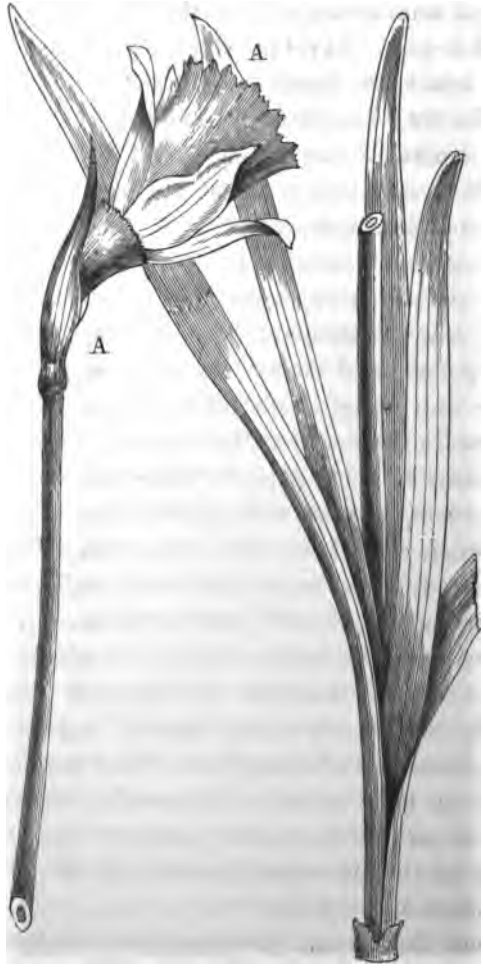
In every country we find that in addition to the average flowers which are visited by many kinds of insects alike, there are others which have generally been modified until they can now be crossed only by a certain group, or even a distinct species, of insect. In these cases we usually find both the flowers and insects marked off from their brethren by peculiarities of structure. Observe, for instance, the long tubes of the common honeysuckle. They are rich in nectar, but can only be reached by insects possessing equally long probosces, such as the *sphinx* moths. The latter are remarkable for their very long sucking-trunks, which are coiled up when at rest. They also well merit their name of "hawk-moths," for their long tapering wings enable them to poise themselves in one position, as a hawk does before striking; and whilst thus hovering, the long proboscis can be uncoiled and thrust down tube after tube of the honeysuckle. The latter flower throws out its richest perfume at night, when the sphinx hawk-moths are flying; and its powerful scent, aided by the light yellow colour of the petals, never fails to attract these peculiar night-flying lepidoptera. Perhaps the most singular of these extremely beautiful specialized flowers is the Madagascar orchid (*Anagræcum sesquipedale*) referred to by Dr. Darwin, which has a nectary nearly a foot in length! Dr. Darwin has inferred from this that there will be found huge moths in Madagascar with sufficiently long probosces to be

thrust down its extremely long tube. No moth in the world was known at that time to possess such a length of proboscis; but since then, Fritz Müller found a species in South Brazil which had one ten or eleven inches in length even when dried.

The limits of our space forbid us to do more than call attention to a few of the numerous modifications of the external parts of flowers. A most interesting and profitable field of research here lies open to the young botanist who studies it in the light of the new philosophy. Every shape, size, tint, streak, colour, and odour has to be accounted for; and we can imagine no other natural science so attractive in the nature of its objects. One is under no necessity to inflict pain, for these summer darlings always seem tempting us to pluck them. Fresh air, sunny skies, green lanes and fields, breezy heaths and moors, windy hill-sides, or dark cool woods—such are the environments of our objects of summer study!

We have referred to the bending or nodding flowers of some species, such as the harebell, snowdrop, fritillary, lily of the valley, daffodil, narcissus, and many others. It will usually be found that nodding flowers thus bend in order to protect the honey they contain from being dissolved away by the dews or rains, which would soon fill the bells if they were always erect like goblets. In the daffodil we have a supplementary organ, the *corona*, in reality more attractive than the other and more legitimate parts of

Fig. 92.



Daffodil (*Narcissus pseudo-narcissus*).

the flower. In the passion-flowers the fringe of large coloured hairs arranged round the interior is simply a fringed *corona*. In some flowers, as the iris, even the pistils add their share of attraction to the coloured parts, for they are flattened out into petal-like objects, and coloured like the perianth. In one genus of our buttercups, the meadow rues, the petals are absent; but the stamens are enlarged, and their anthers so highly coloured that they are attractive enough for insects without such auxiliaries as petals or coloured sepals. In the male catkins of some of the willows, nothing could be more showy than the brilliant yellow of the associated stamens. We cannot be surprised, therefore, that the willows in some measure form an intermediate group between purely wind-fertilized and insect-fertilized flowers.

Some flowers vary their attractive effect by the most pleasing modifications of their petals, which are brought about by the least possible expenditure. Among such we may refer to the fringed or fimbriated edges of the petals of many of the carnations, notably that most lovely of flowers, *Dianthus superbus*, a sub-Arctic and Alpine plant. On the surface of the petals of the bog-bean (*Menyanthes trifoliata*) we have an exceedingly pretty and lace-like effect produced by the numerous hair-like objects which curl over them in every direction.

Small flowers are usually more self-fertile than larger, as we should expect from the theory that

enlarged petals are for the purpose of attracting insects, and thus securing crossing. There is always a certain relation between the number of flowers borne

Fig. 93.

Bog-Bean (*Menyanthes trifoliata*).

on a stalk, and their size. When they are small they are usually numerous—when large, few. Among our British *Leguminosæ* we have almost every intermediate shade of difference between the solitary flowers of the lovely grass-pea (*Lathyrus nissolia*) and the small ones of the clovers and trefoils; and we generally find the *number* of flowers is in proportion to their size.

The wind-fertilized and insect-fertilized groups of

flowering plants, although now pretty well and clearly marked off from each other, were evidently not always so distinct. Even now there are in all floras plants whose flowers are of an intermediate character. Of such are those of the common rhubarb, and some of the docks, willows, plantains, &c., which, although mainly fertilized by the wind, must also be frequently crossed by insects. The abundant two-winged flies (*Diptera*) are the chief go-betweens in this crossing. Mr. Bennett has shown that they often feed on pollen, and frequent all plants producing it. It is possible, therefore, that flowers producing a superabundance of pollen may be direct gainers by it in inducing such insects to visit them; for, although the latter may devour quantities of it, they cannot fail to carry some grains from one flower to another, and so produce the desired crossing effect. Indeed, Dr. Darwin thinks that the conversion of wind-fertilized (*anemophilous*) flowers into insect-fertilized (*entomophilous*) may have been brought about something after this fashion.

Wind-fertilized flowers, as we saw in a previous chapter, are usually borne on trees or shrubs, where their elevation above the ground is doubtless an advantage in enabling the wind readily to carry away the disengaged pollen. To ensure crossing, these wind-fertilized flowers are usually staminate or pistillate, and frequently the staminate flowers grow on one tree or shrub only, and the pistillate upon another. There are, however, flowers which are not

only intermediate between these extremes, but also in the degree of abortion which has caused pistillate and staminate flowers to be formed. Among these may be mentioned the flowers of the spindle tree (*Euonymus Europæus*), ash, &c., wherein we find aborted stamens or aborted pistils. Moreover, this tendency to abort the so-called sexual parts of flowers in the same species varies with climate and soil. Thus, Dr. Darwin shows there is a tendency for the flowers of the common strawberry to become sexually separated in the United States.

Mr. Bennett has further shown that there are many instances in which aborted organs are *latent*, rather than altogether deficient, and that many single-sexed flowers have become so by arrest of development. For instance, Indian corn will sometimes produce flowers of one sex only for a number of years, and then appear with bisexual blossoms! Some species of palms bear female or *pistillate* flowers one year, and male or *staminate* flowers the next.

We have already referred in the present chapter to the "second crop" of flowers which many flowering plants produce, and which are in every respect so unlike the ordinary and well-known flowers of the same species, that the double act of reproduction reminded us of the well-known zoological law of alternation of generation. These singular flowers, unlike the first set usually produced on the same plant, do not require crossing of any kind, either by wind or insect.

Their own pollen is quite effective enough. Consequently there is no necessity for the flowers to open at all, and so we find them permanently closed. On this account the term *Cleistogamous* has been given to them. They are not peculiar to any order or class; although we find them most abundantly supplied to insect-visited plants. Some of the rushes and a few of the grasses are distinguished by their presence. One or two species of exotic orchids are also known to possess cleistogamic flowers. The student may readily find them about the roots of the common sweet violet or wood-sorrel, about six weeks or two months after the ordinary flowers have dropped off. Every day the list of plants bearing these singular flowers is increasing. That they are aborted from the true flowers we have little doubt, for every degree of abortion can be met with, from the cleistogamic flowers of the grass-pea which look as if they were ready to burst into actual blossoms, to the small pin-head-like buds which represent the cleistogamic flowers of the wood-sorrel. Moreover, the tendency to this cleistogamic condition varies with soil and climate, for it has been shown that such flowers as those of *Leersia* are cleistogamous in some places and not in others! It has long been known that flowers like those of the water crowfoot (*Ranunculus aquatilis*) will not expand when they are submerged. In such instances they are fertilized by their own pollen. This is an exceptional condition, met by an exceptional adap-

tation; and we may almost regard it as an incipient cleistogamic stage.

When we open these bud-like flowers, there is no difficulty in concluding they are degraded from the ordinary floral condition. The petals are often still coloured, although faintly, but they are small even to complete abortion and suppression. The stamens are fewer in number, sometimes limited to one. The pistil is aborted, and not unfrequently is reduced to a stigmatic surface, like that in which we ordinarily see it in orchids. The number of seeds produced by these obscure flowers is nevertheless as numerous as those resulting from the showy flowers. Darwin thinks this condition may be due to arrested nutrition. Pollen contains much nitrogen and phosphorus, and therefore is elaborated at the expense of considerable labour on the part of plants. This may be the reason why cleistogamic flowers are peculiar to herbaceous plants, whose bulk is small and therefore unable to store up the force which larger forest trees, like the conifers, can lay by. At any rate, these cleistogamic flowers need little pollen, from one dozen to two dozen grains apparently being the entire produce of one anther, and certainly not more than four hundred grains that of the entire cleistogamic flower of the wood-sorrel! Compare this with the pollen produced by a single flower of the peony, which is put down in Darwin's 'Forms of Flowers,' page 338, at 3,654,000 grains.

Thus it is evident that these closed flowers are gainers by having to secrete less pollen. But there are other advantages. The ovules are converted into seeds within the unopened flowers, and in not a few cases the ovaries are then *screwed* into the ground, and thus buried where they can easily germinate. No auxiliary aids are required to distribute the seeds: they are planted by the parent itself. In one or two instances the cleistogamic flowers are actually subterranean in their habits, and rarely appear above ground. What a singular approach have we in seeds ripened under these conditions, and the underground buds (tubers) of such plants as the potato!

There is something almost human in the manner in which some of these flowers appear to sacrifice the more brilliant positions of life to sheer duty. No corolla flaunts in the sunshine and attracts gay insects; no perfume scents the dewy atmosphere; no elegant shape demands attention on the part of these cleistogamic flowers; they are the hewers of wood and the drawers of water of the vegetable world—gifted with only the rudiments of the organs which render their showy brethren so beautiful! One touch of nature *does* make the whole world kin—whether that of mankind or that of flowers!

CHAPTER X.

THE INTERNAL SHAPES OF FLOWERS.

VARIOUS and versatile as are the colours and shapes of flowers, and striking as are their adaptations to the ends they are intended to serve, they are exceeded in elaboration of structure by the modifications of the internal reproductive organs. Sepals and petals are but auxiliaries — stamens and pistils are absolutely necessary. We may have flowers without the former —it is impossible for them to exist without the latter.

It is natural to expect, therefore, that stamens and pistils have undergone considerably more variations and adaptations than any other floral organs, and we find this to be the case to a degree we little anticipated. Not even in animal structures do we find a machinery so perfect and delicately sensitive as that adjusting the relations between stamens and pistils. Here, again, we have evidence of the most impressive kind, that the majority of flowers require to be crossed by other pollen than their own. The structures of the stamens and pistils have regard to this end, and are generally so arranged as to have their own pollen carried away, and foreign pollen brought, so as to prevent self-fertilization. It is hardly too much

to say that perhaps every species of flowering plant has its own peculiar modifications in this respect, although they may sometimes be faintly expressed.

Up to a few years ago the inner structures of flowers were little known or understood. Sprengel and a few others had noticed peculiarities in varying lengths of stamens and pistils in the same species, in the arrangment of hairs in the throats of flowers, and many other details to which he called attention, which have been verified within the last few years. With the exception of the rough and ready classification of Linnæus based on the stamens and pistils (although chiefly on their number), the shapes, sizes, and arrangement of the internal organs have not received their proper share of attention, even in the more modern "Natural System." In not a few instances botanical conclusions were quite erroneous; as, for instance, where it was pointed out that the reason why the pistil was longer than the stamens in such drooping flowers as the fuchsia, was that the pollen from the latter might fall upon and fertilize it! Now, the floral machinery of the fuchsia is directed toward *preventing* self-fertilization; for even if its pollen falls on the pistil, it cannot fertilize it, seeing that the sticky stigmatic surface is at the end, and therefore is directed away from the falling pollen, although it is directly in the way of an insect seeking to enter the flower.

Of the internal reproductive organs of flowers, the pollen-bags, called *anthers*, and the stigmatic surfaces

of the pistils are the most important. The stalks (*filaments*) on which the anthers are carried, may be long or short according to requirement. The part of the pistil

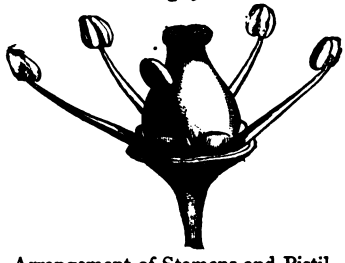
Fig. 94.

Section of Flower of Fuchsia.

Fig. 95.

Arrangement of Stamens and Pistil in Wallflower.

Fig. 96.



Arrangement of Stamens and Pistil in Flower of Vine.

rising from the ovary to the stigma may also be lengthened or shortened. These are auxiliary aids to the effectiveness of the male and female organs.

They are short or long, when shortness and length are in any way beneficial to the flowers; and even in the same species are frequently so modified. Notwithstanding the numerous devices which flowers adopt (as if they were quite conscious of the importance of the act) to prevent their pistils being dusted by the adjacent stamens, these schemes are usually very simple. Perhaps the simplest of all is based on the old doctrine that "prevention is better than cure," for in it we find self-fertilization completely prevented by the stamens being ripe before the pistils, or the pistils before the stamens. The former is the practice most largely adopted, and we find it in vogue among large numbers of our own common wild flowers, such as pinks, geraniums, willow-herbs, mallows, campanulas, gentians, labiate, umbelliferous, and composite flowers. In many of these, as, for instance, the pinks, we may see the stamens coming up to the throat of the flower, ripening there, discharging the pollen, and then withering away. Not until they are shrivelled, and have had all their pollen removed, do the pistils ripen; and then we find that they, in their turn, uncoil their stigmas in the very places previously occupied by the stamens, and therefore where they are likely to be visited by insects whose bodies are dusted with pollen from a younger flower. Such flowers are called *proterandrous*. In the beautiful meadow geranium (*G. pratense*) Sir John Lubbock has pointed out that when the flower first opens, all the stamens may

be seen lying back on the petals. As they come to maturity they raise themselves close to the pistil,

Fig. 97.

Carnation (*Dianthus caryophyllus*), showing cleft pistil emerging above the corolla.

shed their pollen, and then return to their old position. The pistil has not as yet ripened, and all the pollen is thrown on the outside. When the pistil is

ready, its five stigmas separate from each other, with clean stigmatic surfaces. In *Malva sylvestris* the pistils are placed in a nearly upright tuft, whilst the numerous stamens are supported by slender filaments, and are attached to the bases of the pistils. Hence it is absolutely impossible, as the flower is an upright one, for it to be self-fertilized. The flowers of the round-leaved mallow (*Malva rotundifolia*) are similarly arranged, but the pistils are longer, and have the power of coiling in and out among the stamens in case foreign pollen has not been brought; so that in this way they ensure self- if they do not obtain cross-fertilization.

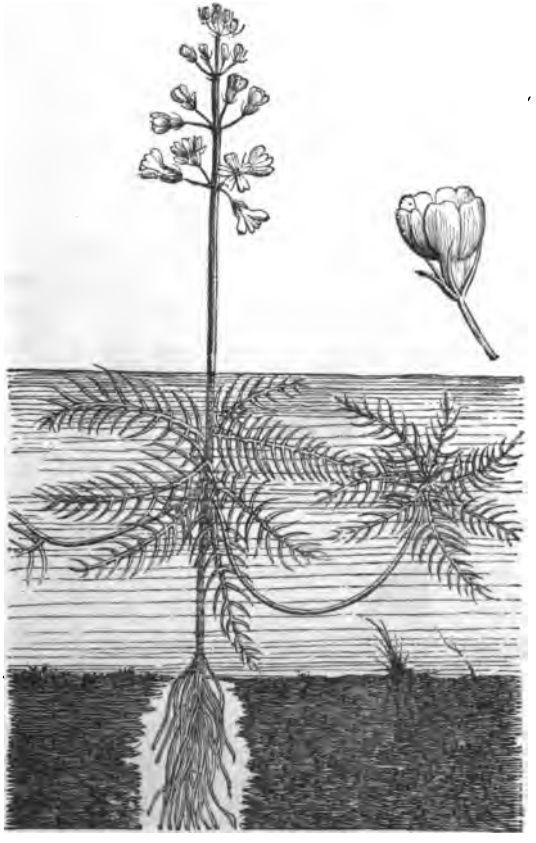
Proterandrous flowers, or those in which the stamens ripen before the pistils, are more abundant than *proterogynous* flowers, in which the pistil appears first. Still we have many of the latter kind, among which occur the figwort (*Scrophularia nodosa*), birthwort, &c. Darwin states that in *proterandrous* species the young flowers are exclusively male in function, and the older ones as exclusively female. So that if an insect alight on the lower part of a spike of flowers (as it usually does) and begins to crawl upwards, it carries the pollen from one flower to another. Even in monœcious plants, like the hazel, where the male and female flowers are placed on different parts of the shrub, not unfrequently the male flowers ripen before the female, and thus the extremest degree of crossing is ensured.

Another simple means by which the pollen from the anthers is prevented from falling upon the pistil is by the anther rupturing on the side farthest away from the pistil. This is the case with most cruciferous flowers, although, singularly enough, when young the stamens have that side of their anthers which opens turned towards the pistil. As they get older, however, their filaments twist them round, so that they eventually open in just the opposite direction to that first threatened. Again, we have in a great measure a means of preventing *self*-fertilization by the long time it takes the pollen-grain shed upon the pistil from an adjacent stamen to throw out its tube and reach the ovary. A grain from some other flower does it much more rapidly, and is thus what Darwin calls *prepotent*. This slowness of a flower's own pollen in fertilizing the ovary is of various degrees. In some flowers it is actually as unable to fertilize it as if it had been a pollen-grain from quite another genus of plants. Nay, in some allied species of *Primulas*, it has been found easier to fecundate the ovary with pollen from another species than from its own.

The most remarkable discovery relating to the structures of pistils and stamens is without doubt that which Darwin announced fifteen years ago. His researches then related chiefly to *Primulas* and the purple loosestrife (*Lythrum salicaria*), and it was shown that these were *Dimorphic* and *Trimorphic*—that is to say, in various species of primroses, cowslips,

oxlips, auriculas, &c., we find the pistil of two lengths, and the stamens fastened in two different places in

Fig. 98.

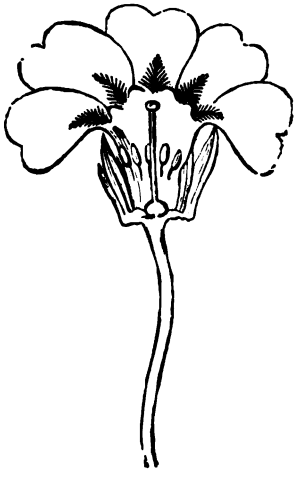


Water Violet (*Hottonia palustris*), a notable *dimorphic* flowering plant.

the two types of flowers, which on this account are called *dimorphic.* In the primrose we had long re-

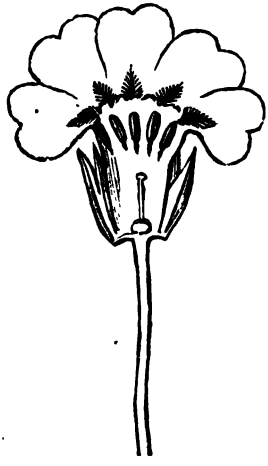
cognized the fact, and the two kinds were called "pin-eyed" (when the stigma of the pistil came up flush with the throat of the flower), and "thrum-eyed" when it stood half-way down. In the latter instance the stamens are grouped around the throat, in the position where the pistil stands in the "pin-eyed" group;

Fig. 99.



"Pin-eyed" type of common Primrose.

Fig. 100.



"Thrum-eyed" type of common Primrose.

whilst in the former the stamens are fixed low down, just on the level occupied by the pistil in the "thrum-eyed." We have therefore a long pistil and a short one; stamens fixed low down the corolla tube, and high up. It was for many years thought a mere freak of nature and nothing more, although it might have been

observed that the two types were nearly equally represented as regards numbers. But Darwin has shown the reason for this contrivance, and the perfect degree in which it is carried out. His experiments (related in his 'Cross- and Self-Fertilization of Plants') do not leave a shadow of a doubt as to the correctness of the explanation. The pollen from the "pin-eyed" primrose is intended to cross the pistil of the "thrum-eyed," and contrariwise. Thus an insect visiting the "thrum-eyed" flower dusts its head with the ripe pollen secreted by the stamens which are visible. In flying to a "pin-eyed" primrose it brings that very part of the head, covered with pollen, into contact with the sticky surface of the pistil. Similarly the point of the proboscis thrust down a "pin-eyed" primrose to where the stamens are fixed half-way down the throat, would just touch and fecundate the pistil, whose stigma stands at the same level as that occupied by the stamens in the other variety. Many other plants besides the primulas (English and exotic) have been found distinguished by this dimorphic character, and there is no reason to doubt that it will be found in existence among flowers in perhaps every part of the world. The water violet (*Hottonia palustris*) is markedly dimorphic, the long-styled pistil projecting far out of the flower. The large-flowered *Linum*, lungwort, bog-bean (*Menyanthes trifoliata*), the *Pyrus japonica*, some of the *Rubiaceæ*, and flowers of various other orders, have been noted as strikingly dimorphic.

Trimorphism is a still more remarkable and complex arrangement as regards lengths of stamens and pistils, to ensure crossing. On account of its being trimorphic, it can only take place where the stamens are more numerous than they are in such flowers as the primrose. The purple loosestrife (*Lythrum salicaria*) may be now regarded as the *type*-plant of trimorphism, as it is that which furnished the original experiments. In this flower, like those of the *Primula*, we hardly find a trace in the external appearance of the beautiful corolla, of the wonderful changes which occur within.

These modifications are confined to the stamens and pistils, which occur respectively in *three* different lengths, hence the name given to this organic peculiarity. The pistil being the most important reproductive organ, Dr. Darwin has called the three types in which its length differs *long*-styled, *mid*-styled, and *short*-styled. The stamens are also of three different lengths, and occur as such in the various flowers. Here we have three sizes or lengths of pistil and three of stamens. It is amusingly singular, but by direct experiment Dr. Darwin has proved that each pistil must be crossed by pollen brought from stamens of the same length. He has also shown that when any agency achieves this (and insects are the only ones which can), the ovary thus fertilized produces a much larger and healthier quantity of seeds than if it had been fertilized by pollen from any other

Fig. 101.

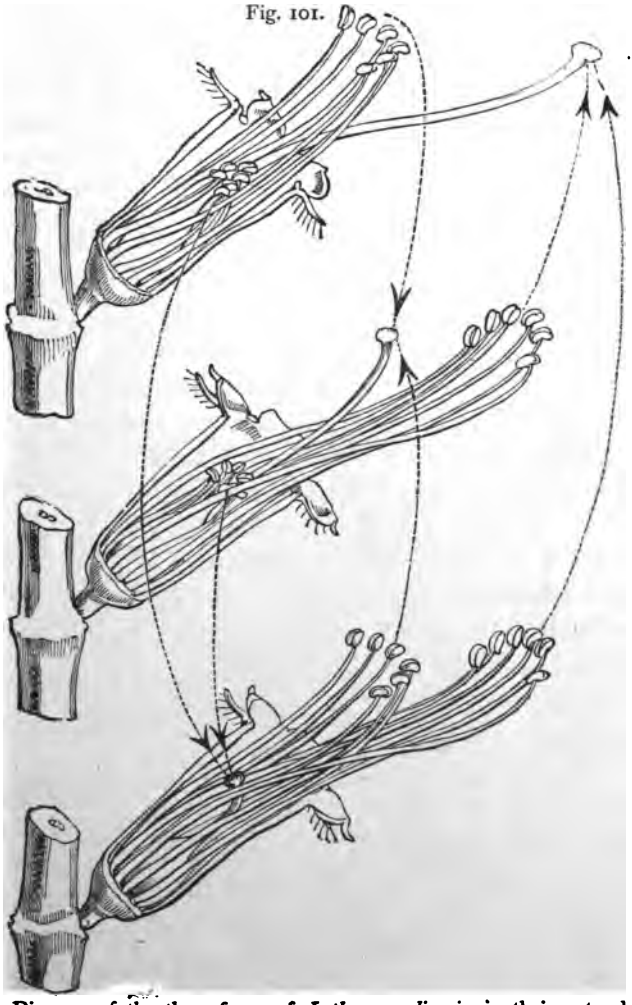


Diagram of the three forms of *Lythrum salicaria*, in their natural position (with petals and calyx removed), magnified six times. The dotted lines with the arrows show the direction in which pollen must be carried to each stigma to ensure fertility. (After Darwin.)

sized stamens. Moreover it has been ascertained that the pollen-grains produced by the different-lengthed stamens are of various sizes, and perhaps we have here the reason why some are more effective than others. This is true of *dimorphous* and *trimorphous* flowers alike. *Long*-styled flowers have stamens which produce *small* grains ; *short*-styled ones those which bear *larger* grains. Now the pistils with the largest styles require to be fertilized with large pollen-grains, because the tubes of the latter have farther to penetrate. This is the reason for the difference in size of the pollen, for it is adapted in every instance to the length of the pistil it can most effectually cross. Even the pistils of these different flowers are modified. In those possessing long styles we find that the upper surface or *stigma* (the most important part) under the microscope appears rough, like the outside of a thimble. Its outline, also, is globular. In the short-styled pistils, on the contrary, the *stigma* is smoother, and the surface is rather concave than convex in its outline.

Darwin has expressed his opinion that *trimorphism* in flowers is an advance in complexer organization than *dimorphism*, inasmuch as flowers marked by the latter character have only an equal chance in favour of any two plants being of equal forms, whilst in the *trimorphic* flowers the chances are two to one. Of course a good deal depends on the number of various flowers grouped together ; indeed, it is diffi-

Fig. 102.

Purple Loosestrife (*Lythrum salicaria*).

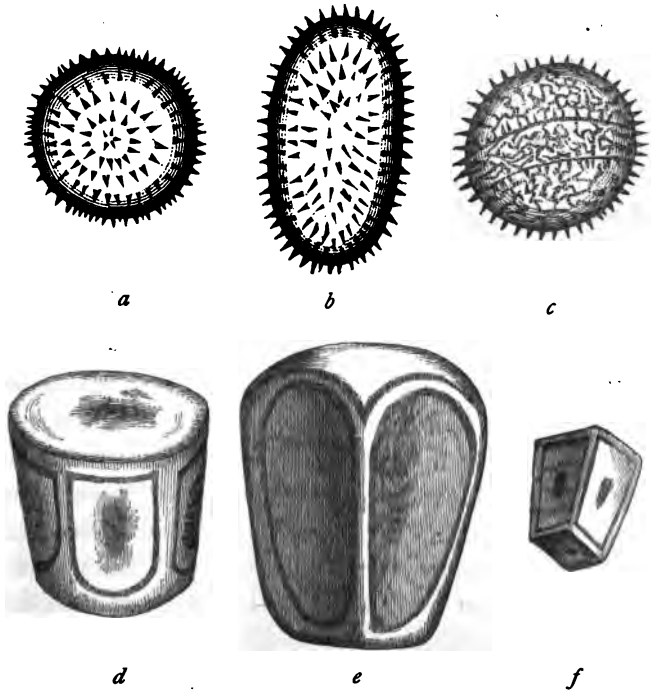
cult to strike any correct scientific average, and the botanist is best engaged in pointing out an internal structural peculiarity which is of such immense service in perpetuating many of our most attractive flowering plants. Darwin has formulated the results of his experiments on the pollen from the three different-lengthed stamens on those of equal-sized pistils. The result will be found fully and strikingly set forth in that most impressive work, 'The Forms of Flowers, &c.' It suffices to say that the reader will there find evidence sufficient and to spare to satisfy him that cross-fertilization in trimorphic flowers is always most effective when a pistil is fecundated by pollen produced by stamens of the same length.

Many other but exotic species of *Lythrum* have been found characterized by the same trimorphic features. Some Cape species of *Oxalis*, lilies, &c., have also been described as trimorphic. It is to be expected that there are more flowers of double-sized than there are of treble-sized male and female organs, seeing that the latter is an advance on, and a higher degree of specialization of, the former. But these two groups are even now obscurely bridged over by some flowers which seem to partake of characters belonging to both.

Not unfrequently we find the stamens of flowers possessing a degree of irritability suggestive of their owning a nervous system. This is the case with the flowers of the berberry, some species of *Erica*, kalmia,

&c. In the berberry we find there are nectaries secreting honey on each side of the stamen. If we

Fig. 103.



Insect-fertilized Pollen-grains :—*a*, pollen of *Campanula media*; *b*, ditto of *Nuphar luteum* (Yellow Water-lily); *c*, ditto of Honeysuckle (*Lonicera periclymenum*). Wind-fertilized :—*d*, ditto of Maize (*Zea Mays*); *e*, ditto of *Triticum sativum*; *f*, ditto of *Carex panica*. (After Edgeworth.)

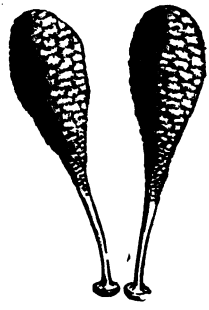
irritate the latter with a small hair, we find it suddenly springs forth and strikes the solid columnar

pistil. It does not fertilize it, however, for the reason that its pollen-bag opens on the *outside*. Now, if instead of an artificial hair we substitute the proboscis of a small moth (and the light yellow flowers of the berberry suggest that they are open late at night), it is evident the stamens would suddenly start in the same manner as when they are artificially stimulated. They would thus *frighten* away small insects, but not before their bodies had been dusted with pollen. After this fashion it will be found that the anomalous habit of some flowers, to be irritable in their reproductive organs, is in some way of direct or indirect advantage in procuring crossing.

We have already drawn attention to the marked distinction between the shapes, sizes, and even *weights* of the pollen-grains produced by wind-fertilized and insect-fertilized flowers. Only an interjectory word is now required to point out that some flowers are crossed by both these agencies, and therefore such species are more or less intermediate. Even under the microscope there can be little doubt as to which pollen is from wind-crossed and insect-crossed flowers, to such an extreme has the differentiation been carried on. In *Althea rosea* and some species of *Cineraria* we have perhaps pollen-grains which show the highest degree of adaptation to insect conveyance, their surfaces being covered over with spiny projections, which cannot fail to make them adhere to the hairy bodies of bees or lepidoptera. Whilst pollen-

grains are usually free, and, in the case of markedly wind-fertilized flowers, quite *dry*, we have others which are grouped in masses. This is the case in the various species of *orchids*, where they are usually imbedded in two gelatinous masses, called *pollinia*, possessing easily detached but adherent bases, which fasten on the probosces or heads of insects in a most remarkable manner. In not a few instances these pollen masses gradually bend forwards after being detached by the inquisitive heads of honey-prying insects; so that they then assume a position which brings them into contact with the stigmatic or female surfaces of other orchids of the same species which such insects may afterwards visit. In some species of *Azalea* and *Rhododendron* the pollen-grains occur in masses fastened together by viscous threads. As these are usually mountainous plants, their pollen may perhaps be most effectively conveyed from flower to flower in this manner. Several other well-known groups of plants have their pollen-grains adhering in a similar manner, notably so in the *Asclepiadeæ*, so that there is not a hard and fast line of demarcation between the orchids and other flowers in this respect.

Fig. 104.



Pollinia of Spotted Orchis.

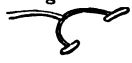
It is no uncommon thing to find some of the stamens of flowers in an aborted or semi-aborted

condition, evidently from disuse, or through their being of more importance to the flower when serving in another manner. In the stork's-bill (*Erodium cicutarium*) five of the anthers are absent, although the filaments are still present. And as this flower belongs to an order which has ten stamens, five of which usually act at a time, there is no reason for doubting that its five aborted stamens once had an active existence. In labiate flowers we get the sta-

Fig. 105.

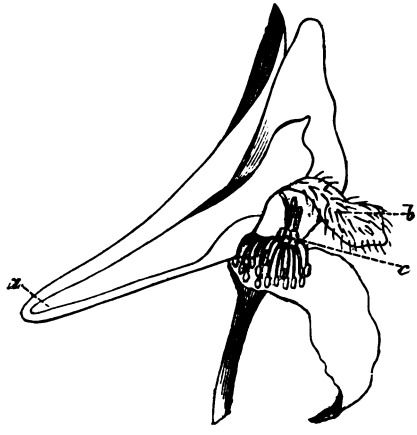
Arrangement of Stamens in Snap-dragon.

Fig. 106.



Connective and Stamens of *Salvia*.

Fig. 107.



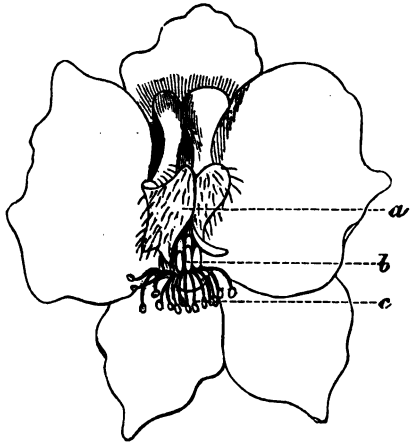
Side view of Flower of *Delphinium* (*Larkspur*). *a*, nectar-tube; *b*, front petal; *c*, pistils.

mens of different lengths, and when these are packed away in their untouched condition under the hood of the corolla, we can see how admirable is the mutual

1. CORIANDER. *Coriandrum sativum*. 2. HEMLOCK *Conium maculatum*.
3 SWEET CICELY. *Myrrhis odorata*. 4 FENNEL. *Foeniculum vulgare*.

arrangement. In the *Salvias* the long stamens work as on pivots, the farther ends of which are aborted anthers. The moment an insect presses against them and just uptilts them, the opposite ends, concealed in the hood, descend by the leverage upon the insect's back, and dust it with pollen in such a manner that it is sure to fertilize the pistil of another flower of the same species.

Fig. 108.

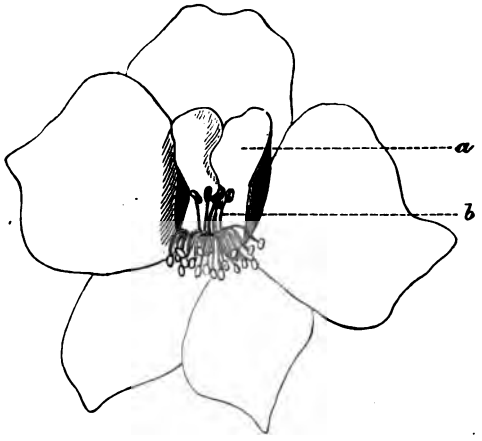


Flower of *Delphinium*. *a*, front petal; *b*, pistils; *c*, stamens. The latter rise from this position five at a time to shed their pollen.

If the "very hairs of our heads are numbered," so are those round and about the throats and interiors of flowers. In not a few instances they unquestionably add to the loveliness of flowers, as in the bog-bean and pansy. But flowers are eminently utilitarian, and we may be sure that every detail of structure,

tint or streak has been called into existence to minister to some requirement. Thus in the lower petals of *Tropæolum major*, or Indian cress, we find the bases narrowing near the throat of the flower, whilst the edges are fringed with rows of upright hairs which act as a palisading, preventing ingress in

Fig. 109.



Flower of *Delphinium*. *a*, upper petals ; *b*, five stamens erect, engaged in shedding pollen.

any other direction, so that insects are thus obliged to penetrate the flower in the direction most likely to produce crossing. Not unfrequently flowers have their throats protected by fringes of hair, as in the wood geranium (*G. sylvaticum*), so that falling rain or gathering dew cannot penetrate the interior and dissolve away the honey secreted there. Laburnum

flowers will be seen to have a ring of close hairs arranged around the pistil, so as to prevent it from being fertilized by the pollen from its own adjacent stamens. In the flowers of the scarlet-runner (*Phaseolus communis*) Sir John Lubbock shows that the hairs terminate a portion of the style within the keel, and rub the bodies of bees with the pollen they have swept up. The meadow vetchling, common vetch, and other papilionaceous flowers have brushes of hairs within their flowers for a similar purpose. Minute brushes of hairs for the purpose of sweeping honey from the bodies of small flies fringe the pistils of the florets in the ox-eye daisy, common daisy, and other composite flowers. In the knapweeds similar "pollen brushes" (as Lubbock very aptly terms them) are possessed by the florets.

Fig. 110.

Closed Flower of *Leschenaultia formosa*, showing pollen being discharged from anthers into the indusium.

Fig. 111.

Indusiate Pistil of *Leschenaultia;* the pollen is discharged into *a* like coals into the hold of a ship.

Fig. 112.

Expanded Flower of *Leschenaultia.*

The flowers of black mullein (*Verbascum nigrum*) have their beauty wonderfully intensified by the violet-coloured hairs which clothe the stamens; whilst in the flowers of the red bartsia, &c. (*Bartsia odontites*), we find that owing to the stamens being *hairy* they effectually close the flower against rain, although they allow bees to insert their probosces between them. The louse-wort (*Pedicularis sylvatica*) employs a fringe of hairs on the lower part of the anthers to prevent the falling pollen from spreading. The white dead nettle (*Lamium album*) presses the rim of hairs into the service of the upper part of the "hood" or arched upper lip, to protect the honey in the tube from rain; whilst the same plant has another fringe of hairs at the base of the tube which effectually prevents small and unserviceable insects getting at the honey! Indeed hairs are not unfrequently used by many other species of flowers for the latter purpose, just as we put iron railing around young trees to prevent the cattle getting at them. Perhaps the most singular use for hairs, however, is that employed by the birthwort (*Aristolochia clematitis*), a singular British outlier of a peculiar order. We find that the long narrow throat of the flower has a large number of stiffish hairs lining it, which point *backwards*, and allow insects to pass on to the bottom of the tube, as Sir John Lubbock says, after the fashion of "an ordinary eel-trap"! Thus the insects can get within, but the hairs prevent their getting out. They are therefore kept prisoners

within the flower until the pollen is ripened and shed on them, whereupon the hairs then shrivel, and the pollen-dusted insects are liberated and issue thence to cross other flowers of the same species. In our common cuckoo-pint (*Arum maculatum*) we have the pistils and stamens grouped in two masses, and aborted specimens of both are seen above and below them. Within the spathe, just where it is narrowed or constricted, is a similar "eel-trap" arrangement of hairs to that just described, and this operates in the service of the *arum* for a similar object.

Enough has been said, however, to indicate to the young botanist what a fund of ingenious amusement may be derived from a more detailed study of the floral structures of our commonest wild flowers. Those who delight in unravelling the enigmas and charades of magazine columns will find in the shapes, tints, streaks, and internal structures of flowers, riddles of the most delightful kind, whose deciphering will not only pass away many a pleasant hour, but leave the student in the possession of a mass of actual knowledge!

CHAPTER XI.

THE PERFUMES OF FLOWERS.

OF all the qualities which flowers possess perhaps none have recommended themselves more to our notice than their *perfumes*. They are the most spiritual part of them, and administer the most æsthetic delight to the human soul. We feel ready to concede the utilitarian origin of all other qualities of flowers rather than that of perfume. There is something so ethereal about it, something approaching to and suggesting immateriality, that we cannot wonder if the stern analysis of modern science produces the sensation of a shock when it declares that this subtle quality had its origin in a simple bid for the services of various kinds of insects. We may have previously concealed from ourselves the fact that many flowers emit odours which are not pleasant to us; whilst others are actually disagreeable and even repulsive. We have exercised a pleasant and unconscious eclecticism, and selected for our delight those which administered most pleasure. And yet it would not be impossible to construct a scale of floral perfumes in which we should have the most delightful at one end and the most disagreeable at the other, and these

two extremes should be almost imperceptibly connected by varying odours. Only the utilitarian origin of perfumes in flowers can explain these apparently antagonistic facts.

With ourselves the perfumes of flowers administer more to our sense of delight in them than either shape or colour. They linger longest in our memories, and are not unfrequently silent pegs on which hang many of our saddest or most pleasing associations. With what delightful sadness does the perfume of the first sweet violet of spring greet the nostril! There is an odour of dead or far-off and long-forgotten memories about it. The perfumes of our most familiar flowers will revive associations of bygone times and old associations sooner and more vividly than anything else in nature.

Yet chemists tell us how little actual matter of the kind is required to create the sense of smell even in man, and we know that it is much more highly developed in many insects. The merest trace of otto of roses will produce in our nostrils a sense of its pleasant perfume. The most inappreciable particle of musk will scent our clothes for years, and it has been shown that even our own sense of smell is able to detect the three one-hundred millionth part of a grain of musk! In this respect our olfactory nerves far transcend in keenness of detection the power of even spectrum analysis. How much more, in proportion, must this wondrous faculty of perceiving

odours be developed among insects; for we have seen that it is so powerfully influential in their lives that some modern naturalists have not unphilosophically suggested that ants and other social insects may actually be possessed of "a language of smell"! Dr. Piesse has shown that perfumes can be chorded like musical notes, so that entirely new odours may be the result, as in Eau-de-Cologne.

Modern chemistry has been able to imitate many of the characteristic perfumes of flowers and plants, and there can be little doubt the already long list of imitations will be added to considerably within the next few years. All of them have been produced from hydro-carbon compounds—those singular complex molecular structures, which appear to break down and be re-arranged by the slightest additions to or subtraction of heat, and certainly under the physical influence of light. Even in the laboratory this is found to be the case, and we can therefore all the more readily understand the influence of sunlight in originating perfumes, or its withdrawal in allowing the denser odours of night-flowering plants to be disengaged. Moisture and dryness both affect the intensity with which the perfumes of flowers are given out—so susceptible is this subtle essence of the slightest changes in surrounding physical conditions. Where the sun's light and heat are most powerfully exercised, as in the Tropics, and where the humidity or dryness of the atmosphere is most extreme—in

short, where the physical surroundings are intensest—there we get the largest number of perfumed and odorous flowers, as well as the species which emit them most powerfully. One species of *Magnolia* (*M. tripetala*) disseminates such a powerful perfume that, in spite of its exceeding sweetness, it produces nausea and sickness. To "die of a rose in aromatic pain," is not so far-fetched a poetical figure as might be imagined.

Many of the perfumes sold for toilette purposes have been manufactured in the chemist's laboratory instead of in the secret bosom of flowers; although at present it is easier to imitate those odours we call *aromatic* than any others. Thus, the Benzoic series of aldehydes includes many useful perfumes, as those of bitter almonds, so commonly emitted by *rosaceous* flowers, such as the hawthorn, meadow sweet (*Spirea ulmaria*), and many others. The well-known smell of new-mown hay is due to a peculiar chemical principle called *coumarin*, which can be produced by chemists artificially; as can be also that of aniseed. It is *Coumarin* which gives the sweet vernal-grass (*Anthoxanthum odoratum*), the sweet woodruff (*Asperula odorata*) and melilot (*Melilotus officinalis*), their characteristic odours. The smallest particle of *naphthaline*, disseminated in a room, will produce the characteristic odour of jonquil and narcissus. Many other combinations of hydro-carbon compounds afford us a glimpse of the possible chemical changes which

take place in flowers, and that cause them to emit perfumes at once so delightful, and to themselves useful in attracting insects to cross them.

Dr. Robert Brown, in his 'Manual of Botany,' has given a classification of the odours of plants, in which he groups them as follows: *Superodorants*, *Subodorants*, and *Nidorants*. The former include all perfumes which, to us and the majority of insects, are delightful or agreeable; among the sweetest of them may be mentioned those of the pink, orange, rose, vanilla, *Nardosomia fragrans*, scandix, narcissus, and jonquil, the white lily (*Lilium candidum*), sweet violet, mignonette, tuberose, wallflower, Virginian stock, &c. The *Subodorants* are those flowers whose perfumes are milder, but still agreeable, as the jessamine, almond flowers, acacias, &c. In the *Nidorants* we frequently find disagreeable odours, as those of rue, garlic, assafœtida, &c. In the *Steralia*, *Datura*, and *Nicotiana*, we have some which can only be exceeded by actual fæces; *Hypericum hircinum* has the rank smell of a goat; and *Stapelia* and *Aristolochia hyperborea* smell of carrion so strongly that their presence soon makes a room actually unbearable.

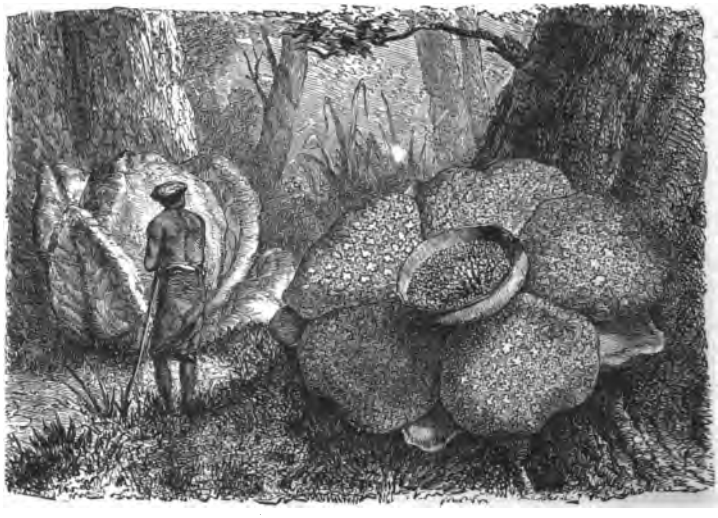
Although the *Stapelia* is a genus belonging to an order (*Asclepiadeæ*) which yields many foul-smelling flowers, on the other hand it includes such sweetly perfumed plants as the well-known *Hoya carnosa* of our conservatories. *Stapelia* is a peculiarly Cape genus, and includes a hundred different species, one

Fig. 113.

Iris germanica, one of the unpleasant-smelling flowers.

of which, however, is a native of Sicily. There are several orders of plants whose members are relatively sweet-smelling and (to us) disagreeable. This fact reminds us of the easy transition with which some organic chemical compounds pass from producing pleasing odours to others which are repulsive.

Fig. 114.



Expanded Flowers of *Rafflesia Arnoldi.*

Propylic ether is one of these, capable of yielding the smell of pineapple or that of stinking fish, according to its slightly different compounds. The strong contrasts in the natural perfumes of some flowers are no doubt owing to a similar series of modifications. Perhaps the most remarkable of fetid flowers is the *Rafflesia*—

a gigantic parasitic flower, a yard in diameter, which grows on the roots and stems of a species of *Cissus*, in Sumatra. These flowers are staminate and pistillate, and grow parasitically on different trees, so that crossing is absolutely necessary. The odour they emit is repulsively carrion-like, and this attracts swarms of flies. Amongst other notable plants with offensive odours are the *Irises*, *Arum dracunculus*, a species of *Roxburghiaceæ*, *Saussurea*, and goosefoot (*Chenopodium*).

Stapelias are not uncommon in our greenhouses, where they are cultivated for the sake of their thick, fleshy, grotesque branches, and pretty flowers. So carrion-like is the odour of the latter that our common English blue-bottle flies often make the mistake of "blowing" them; that is, of depositing their eggs upon the petals, where they not unfrequently hatch. Then we see the young grubs feeling about for impossible food, all the more tantalizing because of the suggestive smell, and eventually dying from a mistake made by their parent! Although many large, bright-coloured, and attractive flowers possess perfumes, we have plants which would be practically helpless unless they possessed them in a high degree, on account of their inconspicuous corollas. Among the latter may be mentioned the lime tree, whose powerfully fragrant flowers are sufficiently attractive to bees to enable them to do without gay blossoms. Anyone who has sat under these trees on some July

evening, and heard the uninterrupted hum above, must be convinced of the utility of scent in attracting the insect tribes. The mignonette also is enabled with us

Fig. 115.

Flowers of the Lime Tree (*Tilia Europæa*).

to lead a humble, dwarfed, and inconspicuous life on account of its exceeding fragrance; and the very qualities which recommend this unobtrusive plant to our own notice, are just those which secure to it insect visits and crossing. The most brilliant flowers, as a rule, are those which possess least perfume; whilst many of them, as the poppy, buttercups, pelargoniums, &c., have no scent at all.

White flowers are by far the most favoured in

nature in the matter of perfume. No other colour characterizes so many sweet-smelling flowers. Darwin shows that there is a considerably larger proportion of *white* flowers which smell sweet than any other, 14·6 per cent. against 8·2 of *red* flowers. We at once see the reason for this when we know that white or light-coloured flowers usually open at eventide, as the white campion (*Lychnis vespertina*), evening primrose, Nottingham catchfly, &c. No other colour would be visible to night-flying insects, and as their perfumes are usually emitted most powerfully during the dark, they must be capital guides to where the flowers are growing, and therefore excellent auxiliaries to crossing. We never find the petals of *white* flowers streaked with such veins as we see on the carnation, mallow, or wallflower; for we have seen that these are "honey-guides." They could only be visible during the day-time, and of no service whatever to night-flowering plants. Hence their absence in the latter. Reference has been made to the possible crossing of *white varieties* of common flowers, and it has been suggested that they are specializations with a view to availing themselves of night- as well as of day-flying insects. If this be the case, it is evident that the simplest specialization of day-loving flowers—when the latter become so abundant that there is not insect aid sufficient to properly cross them all—would be to tell off some of their number to be crossed by the more numerous moths in the evening. Those

whose light colours rendered them visible would be the first to benefit by the change. In the case of the sweet violet we have a well-known *white* variety; and as this is of sweeter and more powerful perfume than the blue, the reason may be that it is so far adapted to night-flying insects.

The *intensity* of perfume in some flowers seems to be related to the length of time the blossom is open. In this way time and intensity are equal. The same amount of perfume emitted by a flower during a fortnight, if thrown out during only a few hours, would be correspondingly stronger. Conversely, we should expect that the strong perfumes of short-lived flowers would be weakened if spread over the duration of long-lived species. In the well-known *Cactus grandiflora* we have a splendid flower which opens about midnight, but dies off by next morning. Its rich perfume is so powerful, however, that it completely annihilates those of any other flowers near by; and in a state of nature could not fail to attract night-flying insects from them to itself by this means. Perhaps it will be found that all flowers which emit powerful odours are short-lived ones: just as we know that all plants which bear large flowers compensate by having fewer of them than small-flowered species. It is said that when insects are excluded from flowers the latter last much longer, as if in the hope of obtaining the succour they require. But when once properly crossed, the corolla begins to decay and drop, as if it were aware that its attractive services

were no longer required. The same is true of the continuance of the perfume.

Mr. A. W. Bennett states that the perfume of flowers generally proceeds from the honey or nectar. Insects are essentially utilitarian, and chiefly visit flowers for the sake of the latter; although some species undoubtedly seek them for their pollen-grains. If there were not a well-marked general association of perfume and honey in flowers, it is very certain that by this time insects would have discovered the cheat. It is on account of the general occurrence of honey or nectar with perfumes, that the latter are serviceable to flowers in attracting insects. Even the honey has a perfume of its own, varying in different plants, just as the sugar of fruits is not exactly the same in any two different species. Insects detect this difference much more easily than we can, and even when some flowers seem to our nostrils to have no perfume, the nectar they secrete is perceptible by its odours to the insect sense of smell.

The honey of flowers is now secreted by special glands, called "nectaries," but Dr. Darwin thinks it was not always so. He is of the opinion that the honey-producing qualities of flowers have been acquired by them, and that insects originally visited flowers for the sake of their pollen alone.

At that time saccharine matter was one of the "waste products" of plants, like the "honey dew," which is often secreted during hot, dry weather by the surfaces of leaves. But when it happened to

occur within the envelopes of the flower, it was utilized for cross-fertilization, became increased in quantity, and stored up in the various ways in which we now find it. Many plants still bear sugar-secreting glands in other places than their flowers, as Mr. Belt has shown in his work on Nicaragua, such as the leaves, petioles, stipules, or flower stalks, and even on the *outside* of the flowers, as on the calyx. Delphino thinks that a sweet fluid is acquired by other organs than flowers, for the purpose of attracting such insects as wasps to be defenders of the plant against enemies. The secretion of nectar is very largely influenced by climature, the same species of flowers bearing it in different quantities in various countries where climatal changes are extreme. Some flowers are both unattractive as regards their petals, and also have little perfume, as those of the holly. But they make up for this by the abundance of honey they contain—just as other flowers compensate for their absence of brilliantly coloured corollas by the sweetness of their perfumes, as in those of the lime tree. The flowers of ivy are slightly fragrant, but their yield of honey is comparatively great. The position of the honey-secreting gland varies in the different orders of flowers and even in the species of the same order, particularly in that of *Ranunculaceæ*. The crown-imperial lily has deep pits containing it at the base of the corolla; the hellebore utilizes its small scroll-like petals for nectaries; in *Pulsatilla* it is secreted

on the stamens; in the marsh marigold by the ovary; in the larkspur and orchids there is a *spur* which bears it; in violets two of the stamens project into the spur of the flower and there produce it. In some of the orchids the sweetness is contained in the tissues of the spur, which apparently have to be gnawed before insects can get at it. Darwin shows that the shape of the nectary and adjoining parts is related to the visits of particular kinds of insects; and H. Müller has further pointed out its modification in lowland and alpine species of the same genus, in order to adapt it to lowland and alpine insects.

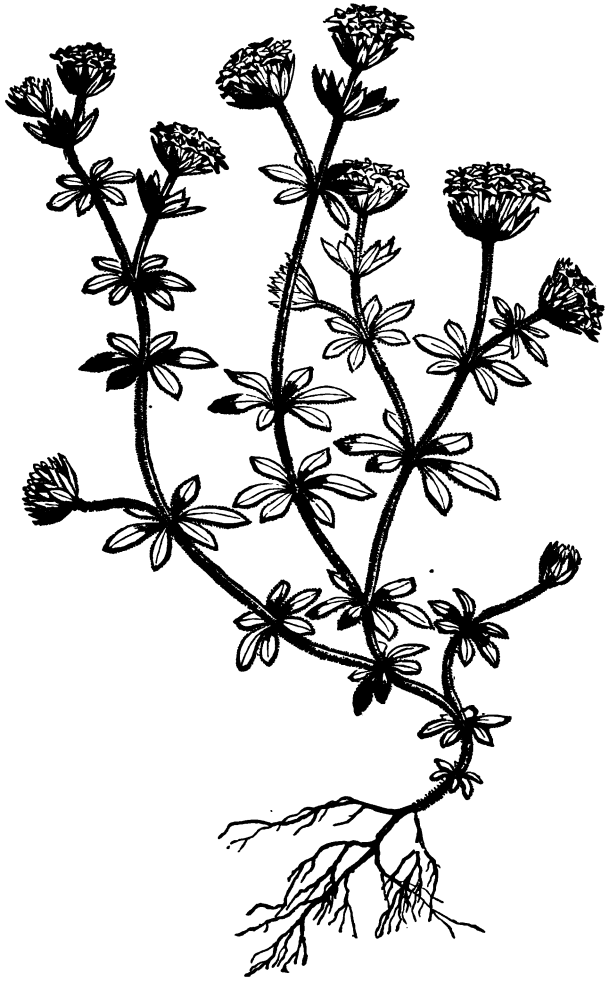
Hence it is evident that in the life-history of sweetly perfumed and honey-bearing flowers, great structural changes have taken place. All of them have been utilizations of structures or specializations of secretions already in existence; and in each case we can see that small means have been employed to produce the most important ends. Natural selection and evolution have evidently been the two controlling forces which have thus modified flowers; and their operations are still at work around us. To our mind this slow but sure and beneficent adaptation speaks plainly of Superintending Intelligence. If it requires the highest intellectual human culture to trace the marvellous series of contrivances, adaptations, and modifications of flowers, it is surely not illogical to believe that nothing short of Creative Wisdom could have directed the processes.

CHAPTER XII.

SOCIAL FLOWERS.

By this term we allude to certain flowers whose inflorescence is remarkable for the manner in which the smallness of the individual flowers is more than compensated for by large numbers of them being grouped together. This is peculiarly the case in three great natural orders, the *Umbelliferæ*, *Dipsaceæ*, and *Compositæ;* although we have other orders in which we find floral effect, as regards colour and perfume, intensified by the small flowers growing near each other. Indeed, the arrangement of such inflorescences as "cymes," "panicles," corymbs, &c., is simply the mode in which this principle is carried out. It is self-evident that if flowers be small, they must be more attractive to insects when densely packed together than if they were scattered over the surface of the plant, and half or wholly hidden by the leaves. As a rule, flowers are usually placed where the leaves are fewest, or where they are so small that they are reduced to mere bracts. Anyone who has observed the mode of grouping such small flowers as those of the ladies' yellow bedstraw, sweet woodruff, or field madder, will admit that it is not a mere accident, but,

Fig. 116.



Field Madder (*Sherardia arvensis*), showing the small flowers collected in umbellate heads.

in view of the fact that their corollas exist for the sake of attracting insects, the very best arrangement which could be devised. The elder-flowers (*Sambucus nigra*) and the Guelder-rose (*Viburnum opulus*) belong

Fig. 117.

Flowers of Centaury (*Erythrea centaurea*).

Fig. 118.

Tubed Flowers of *Cinchona*.

to the same order as the honeysuckle; but how different is the arrangement of the small flowers, densely packed into a hollow umbel-like form in one instance, and collected into a convex head in the other! In each instance a total floral effect is produced on the eye like that which would have resulted from a single conspicuous flower of the same size.

In the case of the small flowers of the Guelder-rose, we are called upon to notice another peculiarity,

which seems to us to be the first step in the differentiation of these "social" flowers. It is one in all probability due to the mechanical laws of growth, but it is none the less useful to the colony of flowers forming the head, or "rose." The *outer flowers are larger* and more striking than the inner; but as if this increase of size had drawn upon their limited stores of energy, such flowers are usually *barren;* that is to say, we have here actual "monstrosities" utilized for the benefit of the inner flowers. The same fact is true of the outer row of flowers in the blue corn-cockle (*Centaurea cyanus*), and those of the *Hydrangea* of our gardens.

In such clusters of flowers as those of the candy-tuft, we have the outside ones larger than the rest. This is doubtless due to the petals having more room for growth, whereas those in the centre press on each other in every direction, as may be seen in the flower-head or *umbel* of the wild carrot (*Daucus carota*). The well-known umbelliferous plants are most remarkable for the difference in size of the flowers. In many of these umbels it will be seen that the total mass is composed of several smaller umbels. Each of the latter will be found to have outside flowers, with *larger* petals than the inside; whilst the flowers which are outside the entire colony are by far the largest of all, their increased size being sometimes very remarkable. Few of these flowers have deep throats, and the honey is secreted openly in such

Fig. 119.

Wild Carrot (*Daucus carota*).

species as the wild chervil (*Chærophyllum sylvestre*), as in a shallow salver, so that small insects can easily obtain it. Lubbock shows that *self*-fertilization in

Fig. 120.

Angelica (*Angelica sylvestris*).

these masses of small flowers is usually provided against by the stamens ripening before the pistils.

The former shed their pollen and wither away before the latter have developed sufficiently to be impregnated with pollen; and on almost every umbel the botanical student may find the internal sexual parts in different stages of development or decay. Enormous numbers of small insects frequent umbelliferous flowers, H. Müller having recorded no fewer than seventy-three as visiting the wild chervil alone. Hence cross-fertilization is most certain to be effected, especially when we remember the simple but effective device by which self-fecundation is guarded against. Müller says that the flowers of the cow-parsnip (*Heracleum sphondylium*) are visited by as many as one hundred and eighteen species of insects. How huge some of these herbaceous plants grow, and the number of flowers they can produce, is best seen in the gigantic Siberian umbellifer, *Heracleum giganteum*. Lubbock shows that the position in which the honey is yielded on the flat flowers and umbelliferous disks of this order, whilst it renders them easily accessible to all other kinds of insects, has the opposite effect upon the butterflies, whose probosces are fitted for sucking deep-throated flowers. This relation of flowers with throats and those without to the visits of different kinds of insects, has been strikingly set forth by that careful observer, H. Müller. Thus he shows that in the knapweeds (*Centaurea*), although each flower-head is composed of small florets, and may therefore be regarded as "social flowers," out of every hundred

insects which visit it fifty-eight are bees, twenty-seven butterflies or moths, twelve two-winged flies (*Diptera*), and two belong to other groups. But the florets of *Centaurea* are tubed, although the tube is short. On the flower-heads or *umbels* of the common carrot, where the small flowers are open and not throated,

Fig. 121.

Astrantia major, a peculiar umbelliferous plant.

out of every hundred insects which visited it there were only thirteen bees, three butterflies and moths; but thirty-one species of two-winged flies, and no fewer than *fifty-two* belonging to other orders. And as Sir John Lubbock remarks, if flowers with longer tubes than those of *Centaurea* had been selected for

comparison, the difference between the different order of insects visiting its flower-head and that of the carrot would have been still more striking.

Few botanists doubt that umbelliferous plants have passed through many life-changes from a simple condition. Indeed, many modifications exist among them, which enable us partly to guess at the direction which the modifications have taken. Their numerous defences in the shape of poisons, the devices for scattering their seeds, and the wide-spread geographical areas over which these plants are to be met with, all proclaim the antiquity of the order, and the countless differentiations which its various members may have undergone.

One of the first evidences of a civilized arrangement of human society is when some of the members of a community are set aside to perform special work for the good of the whole. Advancement in civilization very largely consists in this process of integration. A kind of *division of labour* is thus produced, which is a vast gain to the nation. If a man had to search the mountain sides for veins of metal, then had to smelt the latter, and out of it to form wheels, springs, &c., which, when put together, would form a modern watch, it is very certain he would reckon its value at more than thirty shillings, which is the selling price of an ordinary silver watch. All this work has been done, and by human labour alone, and a watch can be obtained for this modest sum; but the secret of it

is that the work has been performed in divisions by many, and not by one individual. We find this principle of division of labour extant among such communities of insects as bees, brown ants, and white ants, developed in the very highest degree. And a little reflection will show us that it is not unknown in the floral world, and especially among that group we have chosen to call "social flowers." Most suggestive, also, is the fact, that "division of labour" frequently means self-sacrifice by a few for the good of the many. This is one of the most solemn facts in human history—the principle of vicariousness is also that of self-sacrifice and love. Of course we are here referring to the latter as understood by conscious agents. When we find the shadows of similar truths in the organic world, we are reminded of them as symbols. The outer flowers of the Guelder-rose are *barren*, and have become so in the interests of the interior fertile flowers whom they serve. The same fact is true of the outer florets of the corn-cockle, dahlia, &c., as well as of the bright-coloured, strap-shaped florets of the daisy, chrysanthemum, and many other composite flowers. Here, therefore, we have an incipient division of floral labour which, as we shall presently see, is carried out in the *Compositæ* in a remarkable degree.

The order of which our common teazels and scabious are well-known members, is nearly allied to the *Compositæ*, differing from the latter chiefly in the fact of

their anthers or pollen-bags being *free*, and not growing together as we find them within the florets of the daisy or the sunflower. In the abundantly represented *Scabiosa arvensis*, or field knautia, of our cornfields, we find a colony of liliac-coloured flowers grouped on a head, and having the outer ones larger than the rest, so as to make the mass look as bulky as possible.

But the flowers of which the common field daisy and the more impressive ox-eye daisy (*Chrysanthemum leucanthemum*) are representatives, are perhaps those

Fig. 122.

Flower-head of Ox-eye Daisy (*Chrysanthemum leucanthemum*).

which are best entitled to the name of "social flowers." No other order is so botanically gifted in every respect, and the result is a cosmopolitan distribution and adaptation unequalled by any other group. About ten thousand species of *Compositæ* have already been described and catalogued. They are of all habits, annual and perennial, herbaceous and

arborescent. Their leaves exhaust nearly all the patterns and styles of foliage; but their mode of inflorescence is remarkably similar. Notwithstanding these peculiarities, nearly all the species require to be crossed by insect aid, but some few are wind-fertilized; and many of them have an arrangement by which, in case crossing cannot be ensured, they are able to fertilize themselves, and thus ensure a crop of seed.

A very little examination, say, of the ox-eye daisy, will give us side-light glimpses of the changes which have taken place, perhaps in some of the later geological periods, before this characteristic inflorescence has been obtained. We dissect a specimen, perhaps under the common belief that this daisy is a single flower. No botanical mistake could be greater! It

Fig. 123.

Section of Ox-eye Daisy.

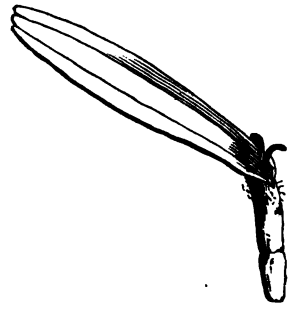
is a *colony of individual flowers*, the latter so diminutive that they are called "florets." Within each there grow the pollen-bags or anthers, packed away in so short a space that their edges actually grow together, and thus they form an inner ring. If we stir up the yellow disk of the daisy with a pin, we find that it is formed by at least a hundred yellow florets, each

cup-shaped and upright, stuck in the fleshy receptacle beneath, something after the fashion in which the ancients thrust their wine-jars into the ground to keep them upright. So that when the receptacle of a daisy

Fig. 124.

Disk Floret of Ox-eye Daisy.

Fig. 125.

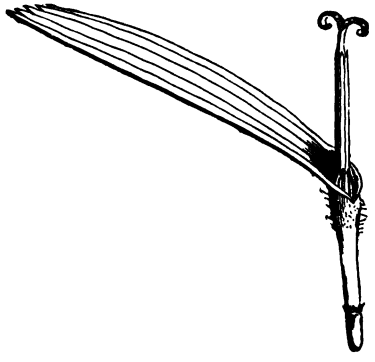


Ray Floret of Ox-eye Daisy.

or dandelion is examined, after the florets have all been plucked off, it presents a regular roughened appearance of holes like those we see on the outside of a lady's thimble. In the big, broad disk of the sunflower the florets are much larger, and the eye detects them at once. If one of them be picked out, it will be seen to resemble very greatly the small bells of the ivy-leaved *campanula* in shape and size. Each of these little florets of almost every species of *Compositæ*, and especially of those which have *tubed* florets forming the yellow disk (one division, to which the dandelion, hawkweeds, and many others belong, having *strap*-shaped florets instead), is wonderfully guarded

against self-fertilization. Dr. Ogle has shown that in the disk-florets of the common feverfew (*Chrysanthemum parthenium*) the ring of stamens ripen before the pistil.

Fig. 126.



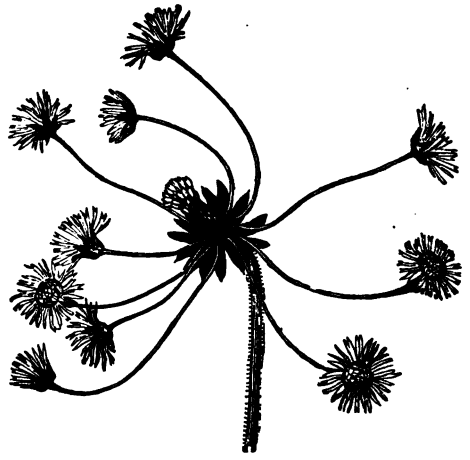
Strap-shaped Floret of Chicory.

They discharge the pollen, and fill the upper part of the floret with it. Then the pistil begins to lengthen, and as it does so it brushes all the pollen outside the floret by means of a tuft of short hairs into which the cleft end of the pistil terminates. Afterwards the pistil forks, and exposes its own clean stigmatic surface to be fecundated by other pollen, all that it has brushed out of its own floret having been carried away or devoured by insects!

Now let us examine the white strap-shaped petals which surround the daisy, and form the well-known "ray." As we pluck them off, one by one, we notice that the base is doubled round an object which projects

upwards. This we discover is a *pistil;* but it is aborted, and has no longer the power to be either fertilized with pollen or produce seed. In many species of *Compositæ*, however, these ray-florets still continue fruitful, although they are only pistillate. No botanist will deny that the daisy had once fertile ray-florets, or they may have been fertile before rays were given to it, as we have reason to believe. Thus the *monstrosities* of the daisy frequently afford us a glimpse of some of the possible changes through

Fig. 127.



Monstrosity in Common Daisy, called "Hen-and-Chickens."

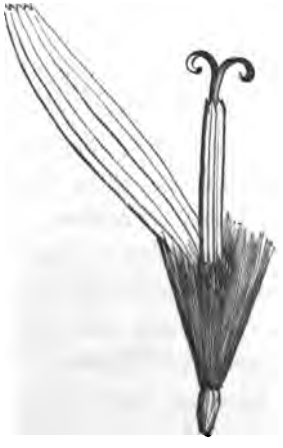
which it has passed. Occasionally we see that form, known as the "hen-and-chickens" daisy, produced by prolification, and due to excess of vigour in

growth. But the monstrous condition to which we especially allude is that where the white petals become *tubular*, but are still infertile. This, we have seen, is the normal condition of some composite flowers; those of the blue cornflower (*Centaurea cyanus*), for instance. So that it would appear as though the daisy once had a ray of tubed florets, and that the latter eventually became modified into strap-shaped ones, still indicating their previous condition by the manner in which the latter are now twisted round the base of the pistils, and more plainly yet, suggesting the last changes through which they passed by occasionally reverting to this bygone state when they assume the "monstrous" tubed forms! Whatever may be the outcome of the new philosophy of flowers, it has done good work, if only by showing that such monstrosities are the result of laws as operative as those which bring

Fig. 128.

Head of Blue Cornflower (*Centaurea cyanus*).

Fig. 129.



Strap-shaped Floret of Dandelion.

about what for the time is the normal condition of flowers.

Notwithstanding the wealth of summer flowers which are loudly bidding for the services of insects during June, nobody will deny that the ox-eye daisy stands a good chance. Few others are so striking or conspicuous. The expanded white petals attract them in crowds, large and small, and their yellow disks are wondrously insect-haunted. So it is with the common daisy of our fields, hardly less showy in the month of May, when it literally carpets the meadows. The pistils protrude above the florets, and as the stigmatic surface lies between the forked cleft, it can be crossed almost by the tiniest insect which crawls over the yellow disk. Some of the winged tribes are doubtless attracted by the abundant pollen, which serves them as food; but others are aware that within the yellow florets there is secreted a tiny drop of honey or nectar. This is the great reward offered by the daisy colony for services rendered. It is of great importance to the colony that the honey shall be secreted, and equally so to preserve it as long as possible, or till every floret is perfectly covered. Then the outer rows of white petals will fall off, for their special work has been done. The yellow disk loses its flatness, and rises up into a cone-like form. As the seeds ripen, this shape is useful, for it forces the seeds out one by one as it assumes this pyramidal shape.

And now we begin to see why the white, crimson-tipped petals of the common daisy, as well as those of

Fig. 130.

Elecampane (*Inula Helenium*).

the ox-eye, and indeed nearly all species of *Compositæ*, should have forfeited their right of individual fertiliza-

tion, and been converted into means for the more certain crossing of the colony of which they form a part. Whenever we see numbers of organic objects, men, or flowers, or insects, crowded together in a small space, the law of "division of labour" is in operation. In a densely populated country or town, division of labour is all-important. It is the same with insects. The butterflies and moths live, for the most part, solitarily. They range over a large area, and are not limited to a single home, like the bees and ants. Even among them, however, we find exceptions, as in the caterpillars of the "processionary moth" and those of our own abundant "little eggar." When these web-weaving caterpillars are crowded together, certain of them are told off as sentries or guards. The same law prevails among the rooks and crows. Among the termites, ants, and bees—all social insects,—the law of division of labour is carried out to its fullest extent. It even differentiates the *shapes* of many of these insects, so that soldiers, workers, drones, queens, &c., have peculiarities of form by which they are immediately recognized. But we never fall into the error of describing them as different species because they are variously shaped. Each individual has its own work to do. Some members of these insect communities cannot even reproduce their kind; but the effect of their combined structure and adaptation is to promote the prosperity and perpetuity of the colony or republic of which all are individual members.

So it is with composite plants, and indeed we might say to a considerable degree with other orders. The floral organs are only modified leaves, less highly, and not more highly, organized. The leaves all do vegetative work: the mouths on their under surfaces absorb the carbonic acid always present in the atmosphere; the carbon is separated from this gas, and the oxygen returned to the air. But the part the leaves fulfil is simply vegetative, whereas the modified and altered floral organs are employed for reproductive purposes. One enables the individual plant to exist,—the other to perpetuate the species to which it belongs. In composite flowers we see this differentiation carried out to its extreme. Like the social insects, the ray-florets act as barren "workers," with no chance of themselves possessing offspring.

We have seen that those white altered florets we call the "rays" assist the unaltered by attracting insects to visit and cross them, and we may at once understand how the alteration has been brought about by studying the cultivated daisies which form the borderings of our gardens. We have white and red and variegated kinds, but all are in the "monstrous" state called "double." These are daisies still further modified, indeed so much so as to be incapable of producing seed, and have therefore been artificially converted into the state which is normal in the ray-florets of all wild daisies. They have been transplanted to richer conditions of growth, as well as guarded against the

keen battle for life with other plants to which they were exposed in their natural state. What wonder that they should respond to this by altered floral details? Every one of the disk-florets has undergone the same change which the ray-florets have passed through some time or another in the life-history of the plant. All are now converted into strap-shaped florets, and hence the disk has disappeared and its space is filled up with the former instead. Such is the condition of all our double garden daisies. The petals still retain, in a great measure, the instinct of their old habit of closing at night, or during rainy weather, but no longer for the original purpose; for in the natural condition of the daisy, not only do the ray-florets open wide to attract insects, but they do something more. Each of the upright, goblet-shaped florets of the yellow disk has a speck of honey in its interior. This would soon be dissolved away by the dews of the summer nights, or the rain showers which fall during the day, and thus one of the attractions offered to insects would be neutralized. The ray-florets, therefore, gather over them at night (when the flower is said to "go to sleep"), or when the gathering clouds forebode a storm, and thus protect both disk-florets and their honey from the wet. They roof them over and nurse them from such damaging influences; and, as at such times no insects are abroad, the colony is no sufferer by such protection, but a complete gainer instead. The early closing, or "going to sleep," of all

our flowers bears some relation or another to this necessity to shield the honeyed nectaries from the rains and dews. Wordsworth tells us that

> "The daisy, by the shadow that it casts,
> Protects the lingering dewdrop from the sun."

But a knowledge of the true structure of this modest little flower reveals to us poetry of even a higher tone; for that very dewdrop is an enemy against which part of its floral mechanism has to protect it!

In the perennial flowers of the common groundsel (*Senecio vulgaris*), which abounds so plentifully as a weed in our gardens, we have an illustration of the non-attractive appearance of those *Compositæ* which are wind-crossed instead of insect-crossed. Compare it with its near kinsfolk the ragworts, whose golden yellow flowers are so conspicuous. It possesses no rays, modified from florets, to be attractive to eyes looking out for flowers: hence its inconspicuousness. On the other hand, as an extreme of the adornment to which the parts of some composite flowers are carried, we have the "everlastings" (*Helichrysum*, *Gnaphalium*, &c.), in which even the parts of the involucre are highly coloured, and continue so. We may also refer to the different colours to which the ray-florets are subjected —to the bright blue of the chicory, the deep orange of the marigold, the purple-tinted florets of the thistles, the wonderful variety of colours we get in the chrysanthemums, cinerarias, asters, dahlias, &c., as evidence of the high specialization of this remarkable

order. In the dandelion, goat's beard, hawkweeds, and chicory, we have all the florets strap-shaped; but here all are perfect, and possess both stamens and pistil.

Fig. 131.

The Chicory (*Cichorium intybus*).

Nearly all are remarkable for opening and closing their flower-heads at a certain time of the day, or "going to sleep," as it is popularly called; and Lubbock believes this habit has reference to the times of appearance of the insects which most benefit them, and their protection from others that are disadvantageous, but whom their generous hospitality could

not well exclude otherwise. We have seen also, that as the habit is usually practised at night or during rainy weather, it must be effective in protecting the nectaries from having their honey dissolved away.

The Nottingham catchfly (*Silene nutans*) closes during the day, and opens and diffuses its perfume only at night, when the proper insects to visit it are abroad. Among the composite or "social" flowers we have such species as the nipplewort (*Lapsana communis*) and (*Crepis pulchra*), which open before six and close again before ten in the morning. Bees, says Lubbock, are very early risers, while ants come out much later, when the dew is off the grass; so that it might well be an advantage to a flower which was quite unprotected, to open early for the bees, and close again before the ants were out, thus preserving its honey for another day.

In the mountain cudweed (*Gnaphalium dioicum*) we have the differentiation carried on still farther, for here the colonies are male and female respectively. In *Echinops* the flower-heads are globular, and each floret has a separate involucel or wrapper. But the variety of modification is almost endless in the composite, in which not the least striking mechanical arrangement is that of converting the parts of the calyx of the florets into the feathery *pappus* or "clock" by means of which the seeds are carried to great distances, and thus disseminated.

CHAPTER XIII.

BIRDS AND FLOWERS.

SUFFICIENT has already been said to show how intimately the structures of flowers are related to the visits of various kinds of insects to them. The importance of this relationship is proved by its universal operation. It exists wherever there are flowers and insects, and the geographical distribution of flowering plants indicates that bright-coloured flowers cannot continue to exist in a natural state unless certain groups of insects are associated with them.

We are now called upon to notice the relation which *birds* have to flowers. In Great Britain there are no known instances of birds being necessary to the cross-fertilization of flowers. In our flora that department is entirely undertaken by insects, although birds are undoubtedly useful in disseminating the seeds. But in various countries there are classes of birds which habitually frequent certain flowers for the sake of their honey, or in order to capture the flies attracted by the honey, and the flowers in many cases have taken advantage of these ornithological visits to be crossed thereby. In other words, these birds carry masses of pollen from flower to flower, and thus un-

consciously fecundate them. In four large areas of the earth's surface, far removed from each other, we have as many specialized groups of birds engaged in the cross-fertilization of flowers. In North and South America and some of the adjacent islands this is effected by three hundred and ninety species of humming birds (*Trochilidæ*), in Southern Africa, Ceylon, India, and part of the Malayan Archipelago we have the sun-birds (*Nectarinidæ*), numbering one hundred and twenty-two species, one of which finds its way to the flowers of the Jordan valley in Palestine. The third group is a still more remarkably specialized one, and includes the brush-tongued parakeets or lories (*Trichoglossidæ*) of the Malayan Archipelago. The fourth class of flower-frequenting birds are the honey-eaters (*Meliphagidæ*), which are characteristically Australian in their geographical distribution.

These birds, except the *Nectarinidæ* and *Meliphagidæ*, have no zoological affinities with each other, and agree only in having similar flower-haunting habits, in this respect resembling the various orders of insects which have been attracted to and benefited by the same objects. Wallace is of opinion that the honey-eaters and the brush-tongued parakeets have been developed in co-ordination with the honey-bearing shrubs and trees which are so marked a feature in Australian vegetation. We have already seen how the humming birds replace butterflies in the island of Juan Fernandez, and perform the work of insects in

cross-fertilizing flowers. In Australia similar floral benefits result from the visits of honey-eaters and parakeets. The latter have peculiar tongues, covered with bristles (whence their name), by means of which they can sweep out the pollen and honey from the bosoms of flowers. Whilst thus engaged their cheeks and heads get dusted with pollen, and this they carry from flower to flower. Only large flowers can be visited by these birds, or those whose polypetalous corollas allow of the head being thrust into the centre. Hence we have, in some measure, a reason afforded us for the larger size of the flowers in regions where such birds are abundant. The large bushes and trees of such countries usually bear very fine showy flowers, in order to attract the birds; and it is found that the brush-tongued parakeets are particularly fond of the flowers which grow at a height above the ground.

The sun-birds in many respects take the place among African and Indian flowers which the humming birds occupy in the Central American flora. Like them they are small, have most brilliant plumage, and possess long thick beaks for insertion into the throats of flowers. There, however, the resemblance ends. The shape of the humming bird is quite different to that of the sun-bird. The former has long tapering wings, so fixed on the body as to allow the creature to poise itself steadily whilst it sucks the honey from the flower over or under which it is pausing. The sun-bird creeps from flower to flower, and seldom takes

honey whilst on the wing. Hence the floral shapes and contrivances of some species of flowers which have perhaps been longest adapted to bird-fertilization of this kind, differ according as the habits of the birds are unlike. We have in Belt's 'Naturalist in Nicaragua' a capital illustration of how the structures of some flowers have become adapted to the visits of birds. A climbing plant (*Marcgravia nepenthoides*) expands its flowers in a circle, and these hang down like an inverted candelabrum. From the centre of the floral circle, and underneath the flowers, there is suspended a number of pitchers, which are full of nectar when the flowers are ripe. The honey attracts insects, and the latter attract birds, especially humming birds. Before the latter can get at the honey-bearing pitchers their backs must brush the open flowers out of which the pollen is ready to be shed, and in this manner they convey it from plant to plant and cross the flowers. In a second species of *Marcgravia* which Mr. Belt found in the woods of San Domingo, the flowers were turned upwards, and the honey-pitchers were at their bases. In this case, therefore, birds had to approach them from above, so that their breasts came into contact with the stamens, and were dusted with pollen.

Both humming birds and sun-birds feed on insects, some species more than others; but they always capture insects attracted by honey. The magnificent flora of the Cape "bush" is much visited by sun-birds,

which may be seen clinging to flower-spikes almost as brilliantly tinted and coloured as themselves. Singularly enough, the African flora, where sun-birds are most numerous, like that of Australia, where the honey-eaters, &c., abound, is peculiarly rich in honey-bearing flowers, which have doubtless been evolved in adaptation to the beneficial visits of honey-loving birds and insects. Some species of honey-eaters are found in the larger of the South Sea Islands, where such showy flowers as the *Metrosideros* abound. And in each case it appears that with such birds are associated large and brilliant flowers not to be met with in those islands where the honey-eaters are not present. One of these birds yields the magnificent red and yellow feathers which have been manufactured into the well-known aboriginal royal robes.

Belt mentions another instance of flowers specialized for bird visitation, just as many of our native flora are adapted to that of different kinds of insects. They were those of *Erythrina*, or coral trees, which bloom in February before they leaf; so that their large red flowers are more visible, and from a greater distance. Each flower consists of a single long petal, doubled over, flattened, and closed, except at one edge, where the stamens protrude. Hence only very small insects can find access to the honey secreted within the base of the flower. Two long-billed humming birds frequent the *Erythrina*, the commoner of which Mr. Belt says may be seen at any time when the flowers are in

1. CHICORY. *Cichorium intybus*. 2. CHAMOMILE FEVERFEW. *Matricaria chamomilla*.
3. DANDELION. *Leontodon taraxacum*. 4. COTTON THISTLE. *Onopordum acanthium*.

bloom. Its bill is very long and curved, and thus enables the bird easily to probe the long flower, and with its extensile cleft tongue to pick up the minute insects from the bottom of the tube, where they have been caught as in a trap, for their only way of exit was closed by the humming-bird's bill! Whilst the bird is probing the flower, however, the pollen of the protruding stamens is dusting the lower parts of its head, and thus the pollen cannot fail to be carried from one flower to another. There can be little doubt that when the commoner flowers habitually frequented by humming birds have been examined by as keen observers as Mr. Belt, the number of floral contrivances possessed by them in order to utilize such bird visits will be greatly increased, and perhaps be found as common as those in Europe which are adapted to insects.

There can be no question that the flora of Central America particularly has been intensified in many respects from the presence of humming birds. The different species of the latter appear to affect various kinds of flowers, and in this manner their services have been applied to as large a variety of flowers as possible. The ruby-throated or northern humming bird (*Trochilus colubria*) has a special fondness for tubed flowers, as those of the common thorn-apple (*Datura stramonium*), and the trumpet-flower or bignonia. It appears to resort to nectar more to satisfy its thirst than for food, depending for the latter

upon the insects it takes in the throats of flowers, or occasionally on the wing. The mango humming bird resorts to the bunch of blossom at the summit of the papaw tree (*Carica papaya*), as well as those of the Malay apple (*Eugenia malaccensis*). Another species of humming bird (*Mellisuga humilis*) passes by the latter flowers without noticing them, and devotes its eager attention to those of the cashew tree (*Anacardium*), the very flowers which the mango humming bird most eschews. The long-tailed humming bird selects the comparatively unattractive flowers of the glass-eye berry, one of the *Scrophulariaceæ*, as its favourites. Mr. Gosse says that this bird is also fond of the blue flowers of the West Indian vervain (*Stachytarpheta*), which abounds in neglected pastures, and that it may be seen during the summer months probing the azure blossoms a few inches above the ground, visiting spike after spike in exactly the same manner as the humble-bee does British flowers.

Darwin states that in South Brazil humming birds certainly fertilize various species of *Abutilon*, a genus of *Malvaceæ*, and that these would actually be sterile without their aid. On the Cordilleras these birds suck the blossoms of *Salvias*.

The same author also refers to one of the Cape of Good Hope plants, *Strelitza*, as habitually fertilized by a species of sun-bird. In New Zealand a bird (*Anthornis melanura*) is frequently seen with its head covered with pollen discharged from a native species of *Fuchsia*.

Our admiration of these co-adaptations increases with our knowledge of them. Surely nothing can tend more to assure belief in a Personal Intelligence superintending all natural processes than the fact that we can see so much continuous contrivance and adaptation in the various departments of the organic world! Humming birds, sun-birds, brush-tongued parakeets and lories, and honey-eaters are themselves among the latest products of ornithological evolution —adapted to the new or specialized types of flowers in the countries where we find them, just as butterflies and moths are the newest outcome of the insect tribes in the northern hemisphere generally.

Although, thanks to the effective manner in which crossing is produced by insects among European flowering plants, we have no need of birds for that purpose, yet many members of our flora are considerably indebted to ornithological agency in other ways for their distribution. With us, however, birds are only utilized for carrying away seed from the plants or shrubs which have produced them. Perhaps shrubs more than herbaceous plants are indebted to bird agency in this respect. The often bright *colours* of their fruit and berries are for the purpose of attracting the eyes of birds, and as these colours are usually brightest after the leaves have fallen, they are therefore most effective on that account.

Even popular observation has taken note of the love of British birds for the red fruit of the hawthorn and

the orange-coloured hips of the wild roses; for a common belief is based upon their abundance that the forthcoming winter will be a hard and severe one, the reason being the idea that these fruits are intended as food for birds when the ground is covered with snow. Many of these coloured fruits have fleshy pericarps, or else the ovary is fleshy and sweet, as in the haws of the wild rose, and the fruit of the crab-apple and wild pear. The berries of the wild service tree, rowan or mountain ash (*Pyrus aucuparia*), holly, haw, yew,

Fig. 132.

Drupe of Sloe, with section of ditto.

Fig. 133.

Fruit of Raspberry.

juniper, ivy, mistletoe, bird-cherry, sloe, &c., are more or less attractive by bright colours; and in the case of those trees whose leaves are not shed when the fruit is ripe, as the holly, the scarlet berries appear to stand out in more prominent relief on account of their background of glossy green leaves. In all the above fruits the outside part is sweetish to the taste; whilst we cannot but observe that many of them contain what are called "stone fruits," or hard endocarps, in which the kernel or true seed is enclosed. These are just the kind of envelopes which would be easiest sundered by

the process of digestion they undergo in the stomach of birds. Anyone may notice for himself the number of seeds of holly in the droppings of birds underneath holly trees. In this manner, owing to the fruits or seed-cases being highly or attractively coloured, birds are induced to partake of them in the winter-time when other food is scarce, and thus the seeds are carried far away from the parent plants, and dropped where there is no chance of their interfering with the latter in its perennial growth. It may be found that the colours of our wild berries are in this way as serviceable to the plants in obtaining distribution for them by bird agency, as those of their flowers have been in attracting those insects by whose aid these very seeds have been produced. It is certain that in those few instances where the fruits of wild plants have been long observed, birds are the chief feeders upon them, as in the case of the mistletoe (*Viscum album*), actually carried from tree to tree only by certain birds, just as we have seen some flowers can only be crossed by certain insects! And even in the case of highly coloured seeds, like the scarlet ones of the *Iris germanica*, which are rendered all the more attractive by the way in which its three-celled capsule opens above and exposes the brilliant colours within, we may find they gain by their maceration in the stomachs of birds.

The succulent exterior of some of our wild fruits, although most attractive, are either poisonous or

emetic; this is the case with the red and black berries of our two species of bittersweet (*Solanum dulcamara* and *S. nigrum*), those of the yew, belladonna, &c. It

Fig. 134.

Cluster of Scarlet Fruits of *Arum*.

Fig. 135.

Fruit of *Atropa belladonna*.

would be interesting to know whether these berries have the same effect on birds as on men and cattle. We cannot eat the scarlet berries of the honeysuckle, but birds devour them. Even that most fatal of poisons, the fruit of the manchineel (*Hippomane mancinella*), can be eaten with impunity by certain South American birds! It may be that the very reason why the coloured succulent berries of some plants are uneatable by or poisonous to other animals than birds is a gain to them, in preventing their being swallowed by creatures in whose stomachs the seeds would be

thoroughly digested and assimilated. Singularly enough, with the increased size of our garden fruits, produced through cultivation, there has often been developed a different habit on the part of our wild birds. They no longer swallow the cherries and plums whole—the latter are too large for that—and so they content themselves by eating away all the juicy pericarp, leaving the stones hanging by the fruit stalks!

If it should prove that the natural colours of wild fruits are in every instance to render them attractive to birds, so that they may be swallowed and carried about, an additional element of interest will have been imparted into our knowledge of plants, and a further guarantee have been given us that not a "speckle, streak, or stain of His unrivalled pencil" has been in vain, whether in the adornment of flower or fruit!

CHAPTER XIV.

THE NATURAL DEFENCES OF FLOWERING PLANTS.

AMONGST a certain class it has seemed matter for surprise and wonder that plants should be possessed of defensive characters. They expect them in animals, but not in plants. Hence when such peculiarities as poisons, thorns, prickles, stings, &c., occur, their presence has been explained on theological instead of on scientific grounds! The same class of people are grateful for the numerous benefits they derive from plants, but can only understand their objectionable qualities on some such theory as that the vegetable world underwent a great change at the "fall of man;" so that the occurrence of these baneful characters in plants must be regarded in the light of a *penal* infliction!

We are happy to believe that this idea, once very popular and wide-spread, is giving way before the discoveries of true science. We can understand the objectionable characters and qualities of poisonous and other dangerous plants better when we understand the use these are to the plants themselves. For, in the extension of that Paternal love and wisdom which envelope organic nature like a garment, are we to

suppose that plants are not included? Defensive and offensive characters are to be possessed by animals, but not by plants! Science cannot for one moment take heed of a hypothesis so dogmatic and unreasonable. It rather prefers to see in the numerous devices connected with the defences of plants, that the latter are included in the same Divine love as that which takes care of animals! The latter knows nothing of the artificial divisions between Life such as we have set up in our classifications, but broods alike over and evolves all, from its lower to its higher forms!

Fig. 136.

Branch of Berberry, showing spines.

Let us for a moment consider how plants are liable to attack. No other organisms are placed in such a condition. They are the prey of nearly all kinds of animal life—indeed, the entire animal kingdom lives by feeding upon them. Hence we have come to regard it as perfectly natural that plants should be eaten by animals, and are only surprised when we find species which cannot be eaten, and others which are actually destructive on account of their poisonous qualities. If we take up a brief for the plants, however, we are bound to show how they alone are able to resist

this universal black-mail—an attack which has been going on during every geological epoch. For, had plants not been able, in some mysterious but understandable fashion, to make head against the universal preying upon them by animals, they would long ago have been extinct. It may be that some of the extinct species have given way because they were unable to hold their own in the keen struggle to which they were exposed. Others have even taken advantage of their critical positions so as actually to be benefited by them. There can be little doubt that the habit of many grasses to grow by *shoots* instead of, or as well as by seeds, is considerably increased by cattle feeding on the flowering parts and keeping them down. Grass is one of the commonest types of terrestrial vegetation, one of the widest spread, and perhaps the most consumed by herbivorous animals. No doubt, also, it is, geologically speaking, one of the oldest kinds of true flowering plants; and yet, in spite of its antiquity and its numerous natural enemies, it is possibly more vigorous now than ever it was before! Not unfrequently we find defensive devices possessed by plants which, if they were exhibited by animals, would be put down either to *instinct* or *intelligence!*

The number of creatures which obtain their daily food by preying upon plants, is incalculable. There are the caterpillars of every species of butterfly and moths, many larvæ of beetles, slugs, snails, birds which consume the young unopened buds, besides

herbivorous animals innumerable which flourish through feeding on vegetation! The wonder is that plants are able to withstand this continuous and universal attack. Only their extraordinary powers of growth and reproduction bear them safely through. But it is evident that any plant having the power of secreting substances which the majority of caterpillars or herbivorous animals dislike, would so far be a gainer thereby. Its leaves would go untouched, and the plant would be able safely to blossom even amid enemies. Such is the case with many of our common buttercups (*Ranunculus*), whose acrid leaves cause most animals to leave them untouched even in the midst of the most closely cropped pastures. In this order of plants we have every shade of internal defence in the shape of unpalatable juices, from feeble acridity up to the strong poison of the wolf's-bane or monkshood (*Aconitum napellum*), and the yet more terrible juices of *Aconitum ferox* of the Himalayas, employed to poison the arrows used in tiger shooting! There is little doubt that the general possession of acrid juices by the *Ranunculaceæ* has enabled them to occupy their existing wide-spread areas.

We have to remember, however, that even as regards the poisons and other objectionable substances secreted by plants in self-defence, the animal world has been more or less co-ordinated with them. Hence some animals can feed on plants which would be dangerous to others. Goats, for instance, can

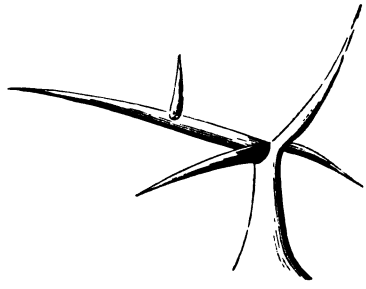
browse on the poisonous *Euphorbias* without any injury. Rabbits can feed on the poisonous belladonna. Goats and sheep will eat the leaves of the wood-anemone, but cattle, and even swine, refuse it. The former animals browse on the succulent leafage of the pilewort (*Ranunculus ficaria*), but the latter pass it by. Indeed, even with our British plants, it is surprising how hardily sheep and goats can devour plants which neither horses, cattle, nor swine dare partake of. Poisonous-leaved plants must also be a good defence against leaf-eating caterpillars; and the care which the female butterfly or moth takes in selecting the right food-plant on which to lay her eggs is well known among entomologists. But we can conceive it possible that frequently the attacks of caterpillars may be of benefit to the species, if not to the plant preyed upon. For when bushes or trees leaf too freely, it is well known that they flower and seed poorly. And contrariwise crippling and preventing the development of leaf-buds increases the number of flower-buds, and therefore of the seeds which will perpetuate the species; consequently the attacks of insect larvæ and even of birds within certain limits sometimes may indirectly be the means of increasing the reproductive powers of plants. The leaves of the foxglove, although evidently disliked by caterpillars, are eaten by slugs with impunity. The fact, therefore, is well established that the secretion of natural defensive poisons by plants is not absolutely

successful, for in the meantime certain animals have become adapted to eat them without injury. At the same time it can hardly be doubted that if plants possessing these poisonous or acrid juices are associated with others of a less dangerous character, they would be likely to be passed over and left alone.

Many plants defend themselves by forming some kind of *bitter* principle in their leaves, as the bog-bean (*Menyanthes trifoliata*), dandelion, southernwood, wormwood (*Artemisia*), gentians, &c.; and this appears to be shunned to a great extent by numerous classes of animals. Some of the mints exhale an aromatic perfume from the oil-glands of their leaves, and as mints are usually bitter the smell may warn away those animals which dislike them before they have tasted them. That herbivorous animals grow up in association with the plants of a country—their accumulated experience extending through long generations developing that kind of knowledge we call *instinct*—is a well-known fact. And that their so-called instinct has been developed is proved by the fact that when English cattle have been transported to the Cape of Good Hope, Australia, New Zealand, and America, at first large numbers of them were poisoned by eating native plants, with which they were instinctively unacquainted. They have gradually learned to recognize their vegetable friends and foes, and comparatively few deaths now ensue from their eating poisonous plants.

The possession of *stinging* cells, like those of the nettle, is evidently intended to be defensive. It is only so, however, against certain enemies, as for instance herbivorous animals; for our nettles are supporters of many insect larvæ. The stiffened kinds of

Fig. 137.



Protective Compound Spines.

hairs we call *thistles*, and which are so abundantly present in some species of those composite plants which on that account receive their well-known name, are doubtless protective against herbivorous animals, although the donkey has a mouth hardy enough to be unaffected by them. These thistles, covering stem and even leaf, are more abundant in some species of *Carduum* than others. Not only must they be protective against larger animals, but also against slugs and snails, which find it unpleasant to trail their molluscous bodies over such a *chevaux-de-frise*. The latter creatures appear to be much more deterred by the spiny mechanism which plants possess than by the

poisons they secrete. The edges of the leaves in the holly curl and stiffen into spines in such a defensive manner that its admirable adaptation suggested one of Southey's best odes! In the gorse or furze the leaves harden into spines, which are defensive against all comers, although sheep feed greedily upon them when they are young, succulent, and tender. In the *Cactus* the fleshy stem performs leaf functions, whilst the true leaves are aborted into the numerous needle-like prickles which cover its surface, and effectually protect it against the animals to whom its abundant juices would be so welcome in the arid deserts where the cactus most loves to grow.

The reason for leaves of plants being *aromatic* has long been a subject of discussion among botanists. Evidently it is not always for the purpose of protecting them against insects, for it seems to have little effect upon the latter. May not its origin be a *physical* rather than a *biological* protection? It is a notable fact that aromatic plants are characteristic of deserts and other hot places all over the world. Tyndall has shown the power which a spray of perfume possesses when diffused through a room to cool it, or, in other words, to bar out the passage of the heat rays. May not the possession of the essential oils in the leaves of such plants be the means of as effectively protecting them against the intense dry heat of a desert sun as if they were partly under shelter! Of course there are many temperate and

even Alpine plants whose leaves are aromatic, which cannot have been so formed for reasons of this kind. But the great abundance of odorous-leaved plants in areas where the diffusion of their perfumes into the atmosphere immediately in contact with them, tends to protect them from the heat of the sun, cannot be regarded as *accidental.*

In some plants we find a considerable amount of *tannin* formed in the leaves, which must be partly protective against herbivorous animals, although it seems to have little effect on caterpillars. In the *bark* of trees we have it usually secreted most abundantly, and in some the bitterness of the bark is extreme, as in the quinine trees. The *pungency* possessed by the leaves and often of the entire plants of *Cruciferæ* is also protective. For when we consider the abundance of this order and its wide-spread distribution, and notice the immunity its species enjoy from attack, we cannot but feel that this peculiar and well-known property is of use to the plants. Under cultivation the pungency decreases, and the plants then become proportionately open to the attacks of insects, as may be seen in our garden cabbages and turnip-crops. The well-known odour of onions and garlic operates upon the insect tribes to a great extent, and is also beneficial to the plants yielding it.

The manner in which first one organ and then another is aborted or modified to serve as defences to the entire plant, is well known to botanists. Aborted

branches, converted into thorns, as in the hawthorn, stiffened hairs changed into thistle-like prickles in the gooseberry, epidermal recurved thorns in the brambles, straight thorns in the wild rose and sweet briar, hairs more or less abundant covering stem, under surfaces of

Fig. 138.

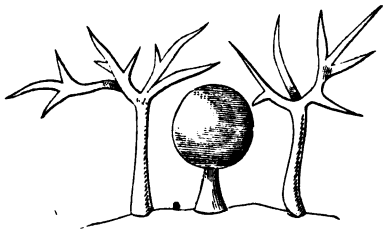
Crane's-bill Geranium (*Geranium Robertianum*), having stems covered with fine hairs.

leaves, or flower-head, as the case may be—these are all to be considered as *defensive.* The thorns not only bar the easy transition of slugs and snails, but deter cattle from preying too eagerly upon the foliage.

In the case of the brambles the recurved thorns are also used as "grappling-irons" for the plant to seize hold of the branches of sturdier bushes, and pull its rapidly growing stems until they are thrown completely outside the shrubs whose aid has thus been ingeniously sought.

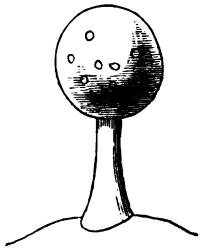
Sir John Lubbock has recently shown that our abundant brown ants are frequently great enemies of flowers. They climb the branches and leaves, and get to the flowers, where they sip the honey intended to attract flying insects to visit and cross-fertilize the flowers. Their own smooth bodies are unable to carry pollen about, even from flower to flower on the same spike or plant; and Darwin has shown that supposing they could be useful enough to perform the latter function, it would be of no importance, for true crossing requires that pollen shall be interchanged between the flowers of different plants, not of the same plants. Hence ants are unserviceable to flowers, if not actually enemies to them. And Lubbock has shown that certain devices are adopted by plants to defend them against the honey-plundering of ants. Chief among these are the *hairs* which may frequently be seen covering the stems and branches. A microscopical examination of them shows that they are often formed of simple branched cells, the branches being especially abundant at the summit, so that they thus form as effective a barrier as such a simple mechanism as this could be expected to achieve. The

Fig. 139.



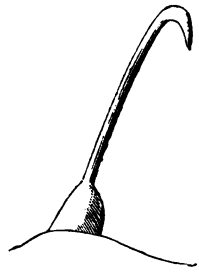
Hairs of Lavender (magnified).

Fig. 140.



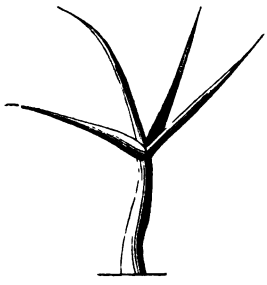
Hair of Moneywort (magnified).

Fig. 141.



Bent Hair of Bean (magnified).

Fig. 142.



Forked Hair of *Aubrietina* (magnified).

Fig. 143.

Clubbed Hair of Avens (magnified).

further study of the hairs of plants, viewed as defensive obstructions to ants, is a simple and important field of practical and useful research open to the young microscopist. Sometimes these microscopical hairs are terminated by a swollen club-shaped summit. All such hairs, spines, thorns, &c., will usually be found bent or directed towards the ground, or in the direction it is expected that ants will climb. Even when the prickles are less thickly scattered over the stem, they will be found most abundant where the attacks of the enemy are most important. Thus in the common Carline thistle (*Carlina vulgaris*), a composite plant, the heads are so beset with a thicket of bristly spines that they must be almost, if not altogether, impassable to ants, which would otherwise soon rifle the florets of their honey. In the blue cornflower (*Centaurea cyanus*), another composite plant, the stem is quite smooth; but the involucres of the flower-head are bordered with recurved teeth, which, as well as the hairs covering the under side, must interfere with the raids of such creeping insects as ants.

These plant-hairs, in not a few instances, have been converted into *glands*, and now secrete the viscous fluid which anoints the stems of flowers, rendering them slippery and incapable of being climbed. In the Nottingham catchfly (*Silene nutans*) only the upper part of the flowering stem is viscid, but this is so to a degree which has obtained for the plant its

popular name. Such a device must therefore be most effective against ants. Kerner has called attention to a most remarkable instance of the use of this deterring viscous fluid, as afforded by the *Polygonum amphibium.* The beautiful rosy flowers of this species are rich in nectar; the stamens are short; the pistil, on the contrary, projects considerably above the corolla. The nectar is not protected by any special arrangement of the flower itself, and is accessible even to very small insects. The stamens ripen before the pistil, and any flying insect, however small, coming from above, would assist in cross-fertilization. Creeping insects, on the contrary, which in most cases would enter from below, would rob the honey without benefiting the plant. *P. amphibium*, as its name denotes, sometimes grows in water, sometimes on land. So long, however, as it grows in water it is thoroughly protected, and the stem is then smooth; while, on the other hand, those specimens which live on land throw out certain hairs which terminate in sticky glands, and they thus prevent small insects from creeping up to the flowers. In this case, therefore, the plant is only sticky when this condition is useful. It will be found, as a rule, that all aquatic plants are singularly devoid of the covering of branched hairs which we have seen are of such use to certain honey-bearing flowers.

In some countries shrubs and trees are found which possess honey-glands elsewhere than within their

flowers. Whenever this anomaly has been carefully investigated by competent naturalists, the explanation has been an additional source of intellectual gratification. Thus, Mr. Belt, in his work on Nicaragua aforementioned, describes a South American species of Acacia, which, if unprotected, is apt to be stripped of the leaves by a leaf-cutting ant, which uses the leaves, not directly for food, but, according to Mr. Belt, to grow small fungi on. The Acacia, however, bears hollow thorns, and each leaflet produces honey in a gland at the base, and a small, sweet, pear-shaped body at the tip. In consequence, it is inhabited by myriads of a small ant (*Pseudomyrma bicolor*), which nests in the hollow thorns, and thus finds meat, drink, and lodging all provided for it. These ants are continually roaming over the plant, and constitute a most efficient body guard, not only driving off the leaf-cutting ants, but, in Mr. Belt's opinion, rendering the leaves less liable to be eaten by herbivorous mammalia.

We have been unable to do more than call attention, in the present chapter, to a number of facts concerning plants, which can only be understood when we regard them as defensive, or in some other way conducive to the well-being of the plant. The further we investigate the wherefore of things, the more are we convinced that the vegetable world is as much under Divine care as the animal; and that the same Providence which takes note of the sparrow falling to

the ground, gives to the lily its perfume, the tulip its streaks, the poppy its colour, and the thistle its thorns —in each case because these gifts are beneficial to the plants themselves, and the species to which they belong! Rightly viewed, the immense amount of new knowledge concerning flowers and plants generally, which has recently been accumulated and is now being formulated, gives us a grander and more reverent conception of the continuity and omnipresence of Eternal wisdom!

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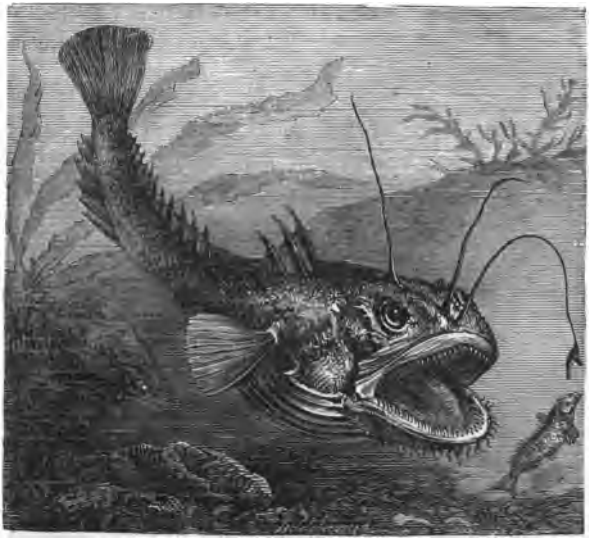

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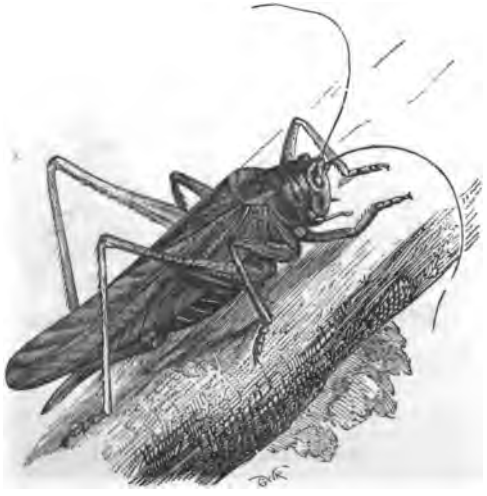

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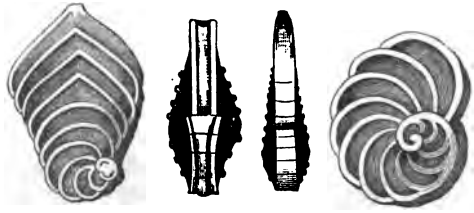

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